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PROCEEDINGS OF THE FIRST ANNUAL U. S. ARMY MATERIEL COMMAND SYSTEMS ANALYSIS SYMPOSIUM

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JUL 7

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WASHINGTON, D.C., 20315

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Technical Report 69-1

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FOREWORD

The United States Army Materiel Command (AMC) sponsored its first Systems Analysis Symposium at the Institute for Defense Analysis, Arlington, Virginia, on November 13-14, 1968. Attendance at the two day symposium totaled 230 persons and another symposium is being planned for the fall of 1969.

The main purposes for holding the Systems Analysis Symposium were to:

a. Discuss common analysis problems within AMC.

b. Allow Department of Defense and Department of the Army to provide their current thinking and plans for the future in the systems analysis area.

c. Discuss the status of the systems analysis groups within AMC's major subordinate commands.

d. To allow individual analysts to get to know their counterparts within AMC.

Robert A. Pollard
Editor

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The following presentations, although given at the symposium, were not available at the time of printing. They will be published in a later addendum.

ABSTRACT

This report (TR 69-1) contains the unclassified proceedings of the first annual United States Army Materiel Command Systems Analysis Symposium, FY 1969, held November 13-14, 1968, at the Institute for Defense Analyses, Arlington, Virginia. Technical Report 69-2 contains the classified section of the symposium proceedings.

Colonel Leonard D. Mitchell
Acting Deputy Comptroller/Director of Programs,
HQ. U.S. Army Material Command

I am Leonard Mitchell, Acting Deputy Comptroller/Director of Programs. Mr. William O. Harris who is the Deputy Comptroller, but is *Acting Comptroller* is attending the Advanced Management Course at Harvard, so I am acting for him also. Now, I hope that concludes all acting in connection with this symposium.

On behalf of AMC I want to welcome you. The general purpose of this symposium is to improve the performance of the AMC systems analysis effort. To aid in presenting the symposium many distinguished speakers have agreed to address the group and we feel we have a meaningful program that will be of benefit to you.

To give you an idea of how far we have come in systems analysis, I would like to relate a brief description of decisionmaking 25 centuries ago. According to the Greek historian Herodotus, the Persians of the fifth century B. C. followed this procedure in making policy decisions: *If an important decision had to be made, they would discuss the question when they were drunk, and the following day the master submitted their decision when they were sober. If they still approved, it was adopted; if not it was abandoned. Conversely, any decision made when they were sober was reconsidered when they were drunk.*

I know that you in systems analysis and related fields would hold that for the male of the human species to give birth is a scientific impossibility. The systems analysis capability within AMC, however, is the offspring of a man who is with us this morning. I am referring to Lt. Gen. William B. Bunker, the Deputy Commanding General of AMC and the guiding light of systems analysis in AMC. It is appropriate, therefore, that General Bunker kick off this symposium. His career is well known to those within AMC; for the benefit of our visitors, however, I will summarize the highlights.

General Bunker was graduated from the US Military Academy and commissioned in the cavalry in 1934. In 1936, he transferred to the Corps of Engineers and attended Massachusetts Institute of Technology, where he was awarded a degree of master of science in engineering. General Bunker has written many papers for technical journals and delivers hundreds of addresses each year in the fields of management, systems analysis, aviation, and engineering. He is the past president of the American Helicopter Society and the current president of the Armed Forces Management Association. In our area of concern, General Bunker designed and established a course entitled "Modern Analytic Techniques for Executive Decisionmakers," a three week course taught first at Princeton and now continued by the Army Logistics Management Center at Fort Lee.

A VIEW OF SYSTEMS ANALYSIS

Lt. Gen. William B. Bunker
Deputy Commanding General
U.S. Army Materiel Command

Welcome to the first AMC Systems Analysis Symposium here at the IDA Hilton. (I understand that President-Elect Nixon has indicated he will reduce the importance of Systems Analysis in the DOD and return more of the decisionmaking authority and responsibility to the military - this may be our first and last symposium).

It is a pleasure to be with you for this symposium. I am, personally, very interested in the application of systems analysis to the many challenging questions, problems, and decisions that we face in organizing, training, and equipping the Army of today and tomorrow. I have the greatest respect and admiration for those qualities of intellect and character that are essential for the meaningful practice of systems analysis, such as ingenuity, integrity, intelligence and courage. I am looking forward to discussing with you both via the speaker's rostrum and through informal discussions at coffee breaks and luncheons the different perspectives we have of systems analysis as well as your views as to how to achieve our common goal–better allocation of Army resources through better decisions and more meaningful (to the decisionmaker) systems analysis studies.

The Purpose of Systems Analysis

It may appear presumptuous for me to be talking to a roomful of professional analysts about the what and why of systems analysis, but, since we view systems analysis from different perspectives, you as a doer and I as a user, it may be worthwhile. I believe that the primary purpose of systems analysis is to assist the decisionmaker in gaining a deeper, and more valid, understanding of the fundamental nature of the problem. The world is far too complex and is changing too rapidly for anyone to have sufficient, ready knowledge of the many different disciplines, organizations, constraints, and relationships between diverse systems and subsystems or be able to make important decisions without the advice of staff assistance and the benefit of special systems analysis type studies. It is worthwhile to note, however, that the object of both the staff advice and the special study is to provide the decisionmaker with greater understanding which, hopefully, will lead to better decisions. This, of course, implies effective communication between the study team and the decisionmaker. The fundamental purpose of a systems analysis study team is, then, to gain a solid understanding of the problem (its important cause and effect relationships, its dynamic interaction with both friendly and enemy systems and tactics) and to transmit this understanding to the authority responsible.

Within this philosophy, the tools of systems analysis are adopted for their ability to contribute to the understanding of the problem. Mathematics, for example, provides an analogue to the real problem that can be manipulated and exercised to gain insight into the relationship between the measure of effectiveness and the various controllable or uncontrollable parameters. The precise answers that result are not in and of themselves so important, for each answer is dependent on a number of assumptions and estimates, and therefore, represents only one point out of a universe of possible point estimates. What is important is to know the assumptions that will make alternative B more effective than alternative A or to know what part of the system represents the weakest link or limiting factor in the performance of the total system. I stress this *kick* of understanding because it is simply impossible for us to predict the state of nature that will exist 5 years in the future, although some parameters are easier to predict than others. In essence, we know that for any state of nature that we predict, and the more detailed and precise our prediction, the more sharply we define our single point estimate of the future and the greater the likelihood we will be wrong. As you know, the probability of any particular discrete event occurring is approximately zero and yet events with zero probability occur every day, if simply because one event out of the infinite possibilities must occur. This semiphilosophical view of systems analysis is background, and I now want to discuss some of the specific practices of current systems analysis that I find disturbing.

Probability Models

As you might expect from my comments on predicting versus understanding, I find the use of probability, and particularly expected value, models highly disturbing. I fully realize that random occurrences can and do play a vital role in determining the outcome or the effectiveness of particular systems in particular situations. Once I have an understanding of the factors that cause the peculiar behavior of a particular system in a particular situation, I can further this understanding by introducing random errors or variations into my model. I can also sharpen my intuition through the use of statistics to indicate when a change in a variable under my control will result in a statistically significant increase in system effectiveness or the outcome of the duel. Note, however, that this introduction of the random elements contributes only to the refinement of understanding or evaluation that was reached on the basis of the underlying cause and effect relationship. The point is that at times the added effort to build a Monte Carlo model may be worthwhile; usually, however, I would venture that increased parameterization of both controllable and uncontrollable variables as well as increased emphasis on the exercise and interpretation of model results will yield a greater payoff. The results will be more easily understood by the man who must make the choice.

Apparently, most of us are aware of the difficulty and relatively low return on effort for Monte Carlo type analysis so, instead, we use expected value of maximum likelihood models for analysis. When the fundamental nature of the outcome is essentially binary (of a hit or no hit, win or lose, go or no go), I find it very disturbing to see this represented by an expected value, which implies a whole continuum of possible outcomes. The weather forecast is a good example of this. What does a 20 percent probability of rain tell me? It says that I should carry a 20 percent umbrella. I am aware, of course, that if I take note of all weather forecasts from here to eternity for those days when a 20 percent probability of rain was given, it should rain 2 days out of every 10 (assuming the forecaster's original model was valid). What I want to know, of course, is how will rain affect the performance of my system, the outcome of the battle, or attendance at my picnic and, conversely, how will good weather affect these performances or outcomes? Armed with this knowledge as to particular outcomes for particular discrete situations, I can understand and cope with the problem far better for both the rainy and sunny days than I could possibly do with knowledge of only the expected value for system performance in 20 percent rain and 80 percent sun--a phenomenon which never occurs. We don't get to fight the real battle an infinite number of times so that expected values would be meaningful; we fight it only once. At the very least, the decisionmaker needs to know some measures of the variation of outcomes around the mean or expected value.

Some time ago, I was briefed on a design study for a Multiple Artillery Rocket System (MARS). The study had used an expected value method for distributing tanks throughout the target area. Over an infinite number of trials a missile was equally likely to hit a tank any where inside the target area with a probability equal to the collective top surface area of the tanks divided by the total surface area of the target area. Although the model (so I am told) was statistically impeccable, it was not very intuitively satisfying to envision discrete tanks regarded as being spread uniformly (like peanut butter) throughout the target area. Needless to add, that each projectile hitting the target area killed some percentage of a tank, and the analysis provided no estimate as to the variance of the results. Again - on any given try you either hit a tank or you don't and adding up percentages of tank areas hit seem like a futile excerise, statistically correct perhaps, but not very valid.

War Games

War games are another tool of the systems analysis kit that I regard without enthusiasm. War games have been around for many years and are mainly useful as a teaching device. When they are used as a basis for evaluating alternatives, they are highly constrained to a very detailed specific situation; they are expensive to run, and they cannot be replicated (if just because of the learning of the player). Typically, only a few war gaming models are developed (for they are horrendously expensive both to develop and to operate) and, invariably, they are developed from some well-known highly documented battles from an earlier war. Thus, it was that when I went through Command and General Staff School we fought the battle of Gettysburg; current students are fighting the battle of the Fulda Gap. First, one might note that we are very unlikely to fight again at Gettysburg, and it hardly provides a good estimate of what to expect in future wars; neither, of course, does the Fulda Gap. It is also notable that the tactics used in a situation relate to the specifics of the enemy threat, the terrain, the capabilities of the friendly forces, and the experience and ingenuity of the friendly and enemy commanders; together these factors interact to determine the outcome of the game, but it is not possible to identify the cause and effect relationships, or to extrapolate the results of one war game to another situation.

An example of this problem is the recent Combat Developments Command (CDC) Cheyenne War Game study that showed a force armed with Cheyenne aircraft was more effective than an equal cost force not armed with Cheyenne. To obtain authorization to procure Cheyenne, the Army had to agree to an equal cost tradeoff of Cheyenne for some tanks, tube artillery, etc. For that specific scenario, the tradeoff may have helped the Army by providing a more effective force for the same total cost, but we don't know what the net effect of the trade will be for the many other possible situations that may occur although the Cheyenne would be less effective than tanks or artillery.

Efficient System in an Inefficient Environment

In performing our cost effectiveness systems analysis studies on competing weapon systems we use the technical performance characteristics of the system and exercise them in our model. Recently, I have noticed a credibility gap between the efficiency and effectiveness of system performance in the paper study and its performance in the real world. For example, I have been watching with great interest the volume of small arms ammunition that is consumed each month in Vietnam. Over 2 million rounds of M16 ammunition are consumed each month. During the same period, enemy casualties have been running about 10,000 killed in action each month. If we assume all enemy killed in action are caused by small arms fire, a highly tenuous assumption, we get a probability of kill of .005 per round. I recently saw a figure of .015 used in a study for the probability of kill. As an extreme assumption concerning the cause of enemy casualties, the probability of kill used in the paper study is 300 percent greater than that which can be observed in the real world.

A television news commentation once noted that the United States had now dropped a bomb for every person living in North and South Vietnam. Although this is obviously an exaggeration for rhetorical purposes, it serves to emphasize the point. Undoubtedly, we determined the Circular Error of Probability (CEP's) and lethal areas and figured the relative cost effectiveness in terms of dollars per person killed or per sampan destroyed. Yet, we have dropped a huge quantity of bombs and the enemy's ability to fight and will to fight seem undiminished. One can only wonder at the apparent lack of consistency between paper studies and the real world and hope that greater efforts toward improving the validity of analyses will be forthcoming.

The Gama Goat effectiveness predicted a large increase, somewhere in the order of 250 percent, over its predecessor, the M37. Supposing that on the basis of our estimated effectiveness and relative costs we were told to replace the M37 with the Gama Goat on a ratio of two to one. Do we have sufficient confidence in the validity of our measure of effectiveness and this estimate of improved capability to accept such a trade? What is the real value of this increased mobility capability for a vehicle that will spend 80 percent of its time sitting idle in the motor pool, 85 percent of its mileage on paved roads and only 15 percent of its time on cross country missions which require the increased mobility? In the same vein, of what value is increased accuracy to a rifle when 95 percent of its shots are fired at an unseen enemy in an unknown location?

How sensitive are our decisions to this problem of the efficient system in an inefficient environment? How can and how should our systems analysis studies cope with this problem?

Optimization versus Tradeoffs

This is obvious and straightforward–given any particular specific mission and scenario, modern engineers can design a vehicle (a system) to perform that mission under those conditions in an optimal (most cost effective) fashion. To maximize performance for this particular situation, however, they have had to degrade its capability to perform other unspecified or unknown missions under other unspecified or unknown conditions. Thus, the use of missions and scenarios is a basis for determining most cost effective alternatives as an undue premium on the system optimized for a particular set of missions and circumstances. It unduly penalizes the more flexible all around system that is effective across a whole spectrum of missions, scenarios, but yet costs more to provide this added flexibility. Needless to say, since we cannot pick the missions, threats, environments, and tactics of the future with any degree of accuracy, we are more concerned about having adequate capability under all conceivable conditions rather than "optimum" capability for what appears to be the most likely situation. This question of flexible capability as opposed to optimized capability is even more important if one views warfare from the viewpoint of game theory, where an intelligent opponent will attempt to chose the strategy that exploits his strength and our weakness than to have particular strengths for any possible set of conditions that may occur.

Closing

The developing of alternatives, the evaluation of alternatives and, finally, the choice from among the alternatives weapon systems requires the participation of the engineer, the comptroller, the military user, the systems analyst and the manager. The engineer, the comptroller, and the user, however, are each responsible only for a particular aspect of the system, or for only a particular element of the choice. Only the analyst and the manager are responsible for coordinating and integrating the diverse elements, disciplines, organizations and constraints for the overall evaluation and decision. In the modern world, where the costs of each weapon system are so high, and the fate of the free world is at stake, the importance of good military decisions cannot be exaggerated. Although there is no doubt that final responsibility and authority for these decisions rests with the manager, he regards systems analysis as his strong right arm to assist him in understanding the important issue and identifying the relevant applications of value judgments. In short, the practitioners of systems analysis bear a tremendous share of the responsibility for the decisions that determine the security of the United States and the free world.

THE SYSTEMS ANALYSIS EFFORT WITHIN AMC

Mr. William J. Tropf
Chief, Systems and Cost Analysis Division
Comptroller/Director of Programs
HQ, U.S. Army Materiel Command

Welcome to SAS-69. This is the first such affair which we, in AMC, have sponsored in any formal sense. We hope it will be both enlightening and fruitful for you and that it will not be the last.

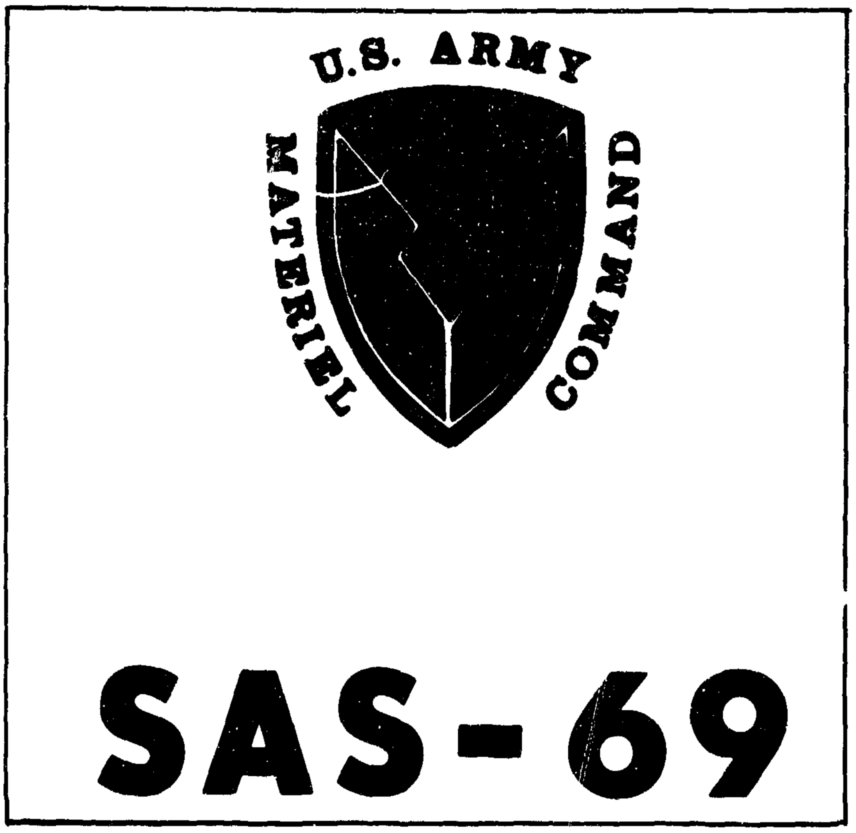

Chart 1

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We also want to extend a particular welcome to our distinguished guests, as well as our gratitude for the time taken from busy schedules to visit with and provide us the benefits of their experience and philosophy in the general field of what we have come to know as systems analysis. Later we will be privileged to hear the honorable Dr. Enthoven and Mr. Frank Parker. Sandwiched in between, preceding these celebrities and following General Bunker as I am, leads me to some psychological inadequacy and a general feeling that whatever I can offer will be strictly anticlimatic, from both directions. I ask, therefore, your most compassionate indulgence while those of us who are usually known as *hey-you*—or alternatively as *hey-you over there*—do the best we can.

I'd like to digress for a moment from the main theme and remark on something which has struck a very responsive chord. Similar to General Bunker, my own introduction to a military career began in close association with the cavalry. Now this does *not* remind me of a story but, rather, it occurred to me that systems analysis being a young man's game, many of you may be unaware of this institution as it existed some 30 years ago—except as something to sort of jazz up the action of TV westerns. So bear with me please on a brief excursion.

The cavalry of those by-gone days was a military unit whose Table of Organization and Equipment (TO&E) consisted of a mixed bag of horses and men; the basic unit was the horse. The worth ratio of the time was generally conceded to be about 5 to 1, favoring the horse, under a 40 to 8 formula which I understand was worked out by the French army. My own impressions were that cavalry units, by a process known as aptitude testing, were stocked primarily with city-bred boys who had difficulty distinguishing species of the higher order grazing animals—much less the ability to stay on top of one. Cavalry charges, which were indeed a fearsome sight and reached momentums of 35 miles per hour, usually concluded with the objective reached *by all of the horses and approximately 60 percent of the men.*

In the cavalry both horses, men, and their surroundings were required to be meticulously maintained at all times. This task, of course, fell largely to the men; the horse only incidentally getting in the way and generally contributing in a negative sense only. It was conceded that the horses also ate better than the men, and a modified set of the rules of war existed for the horse which had a distinctly more liberal interpretation. Moreover, in any dispute between the two those in authority tended to option for the horse. It was clear to all of us that the horse had the upper hand, and even the officers suffered under this dichotomy. It was rumored at the time—falsely as it later turned out—that the officers of the 7th were assembled every Monday evening and required to repeat the words, "I will not split my force," a number of times. It was obvious, though, from the thrust of the training that if the United States ever again become involved with the plains Indians it was just going to be too bad for them.

Chart 2 is an action shot of the cavalry normally encountered on the exercise field. The device on top of the horse is known as a saddle—in this case, specifically, a McCellan saddle—and was the most diabolically uncomfortable piece of equipment ever introduced into the western world, flawlessly engineered with a guarantee to get you where it would hurt the most. The picture illustrates why I also achieved transfer from the cavalry, accomplished mostly through a superior display of ineptness *and* malingering.

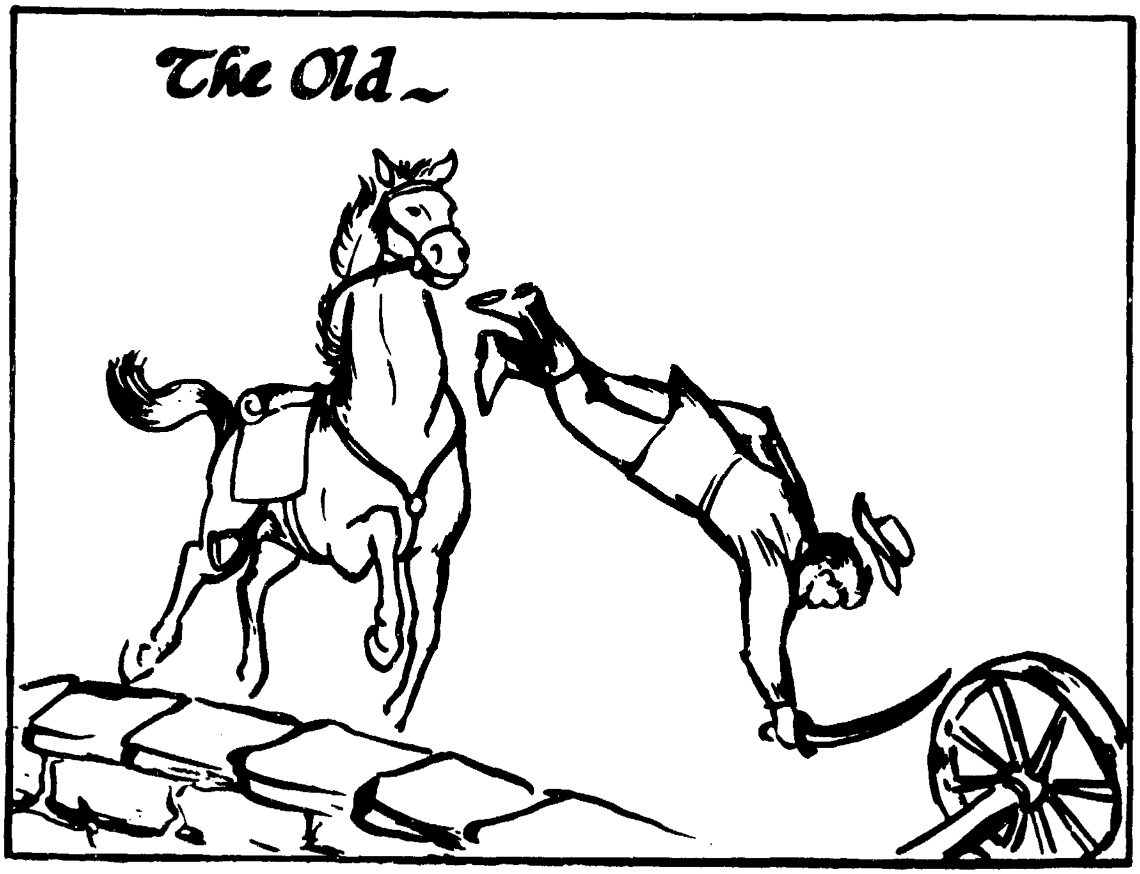


Chart 2

Well that's the old and so we go to the new; we note that the cavalry never really went away but experienced only subtle changes in form. One, or at most two, men are required to steer this device so that the force/worth ratio now is reduced to something approaching parity. As many as 35 or more additional personnel can go along for the ride, and since their role is passive need not be assiduously trained in standing stable duty.

Chart 3

On the surface it would appear that the cavalry changed little in its objective output over the years, particularly when viewed from a macro-perspective vantage point. I suspect this same attitude applies in this general area of systems analysis. "The more things change, the more they remain the same" is a current cliche and one all too glibly applied in a macro-outlook on conditions and evolutions whose more detailed inner constituency may either not be understood or dismissed as a matter of no interest. It remains, then, for us to examine institutions (particularly those with invariant names) in terms of their micro details if we expect to arrive at any evaluation of the sum of their impacts. Like the cavalry, it frequently helps if the observer has some familiarity with the inner details of both the old and the new, if a real assessment of how profound these changes might be is to be made. The note, therefore, for this symposium, is to examine systems analysis in AMC in some of its detail. My own contribution towards this objective will be covered through these five main topics.

To begin with, I think the purpose of SAS-69 is clear. Basically we desired the opportunity to assemble AMC personnel who had an impact upon, or were impacted by, systems analysis in AMC. The intent is to perform introspection and a self-critique of what we do, the details of how we do it, how well we may do, and whether or not we are making any appreciable headway at all.

So as to ensure that we do not become too inbred in these deliberations, we have invited guests of distinguished accomplishments in the field from outside of AMC, who will not only give us their own approaches and concepts but will also provide us with a candid assessment of their view of AMC.

SAS - 69 OUTLINE

- PURPOSE OF SAS-69
- ORGANIZATION FOR STUDIES & ANALYSIS IN AMC.
- WHAT HAS THE PAST LOOKED LIKE?
- WHAT DOES THE FUTURE PORTEND?
- WHAT SHOULD AMC BE DOING?

Chart 4

I should make it clear that chart 5 is not the complete AMC organization for studies and analysis. In AMC systems analysis and studies involves, and is the responsibility of, almost every cell in the command, both by direction *and* necessity. The chart identifies only those organizations formally established, whose activities are devoted to studies and analyses or systems analysis in one form or another. To summarize at the headquarters there is a special assistant to the commanding general for systems analysis. The Army Materiel Systems Analysis Agency (AMSAA/AT Aberdeen) is the central technical capability for AMC. There is a systems analysis group and a cost analysis office at each of the commodity commands, and these vary in authorized size from about 9 to 25 and between 5 and 27, respectively.

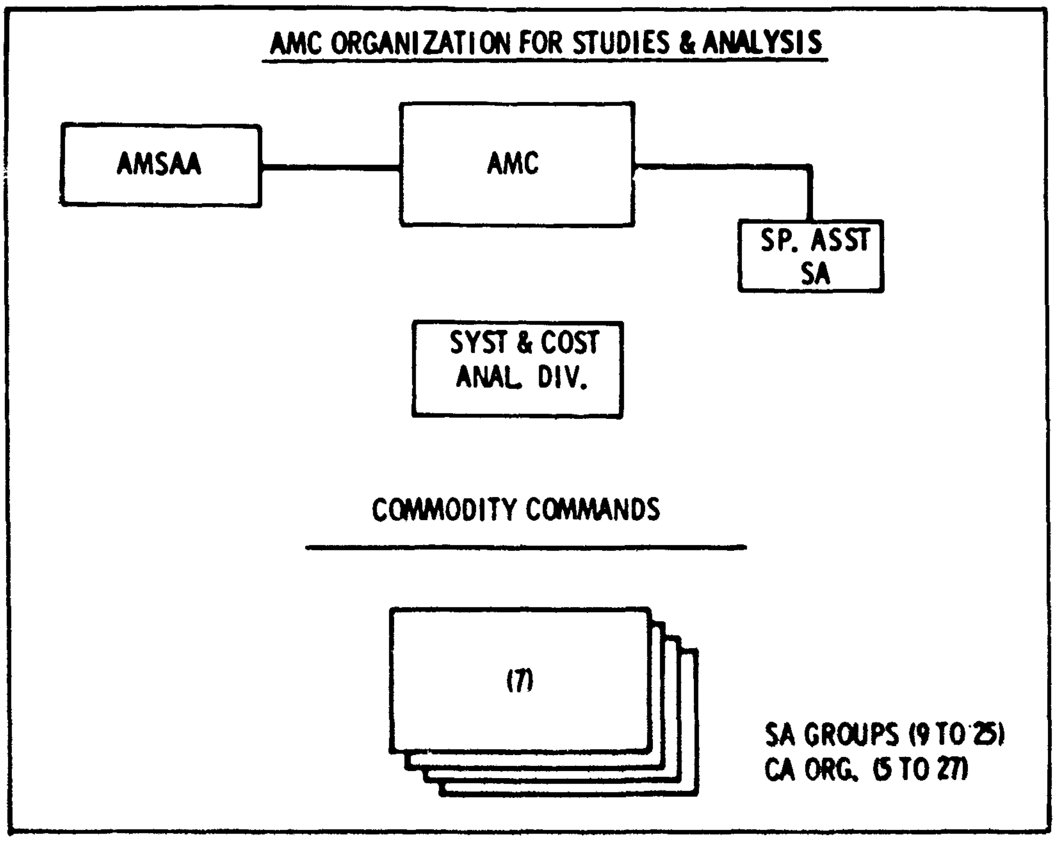


Chart 5

If we can move on to a consideration of what the past may have looked like, it seems to most of us that the last 2 years have been marked by a heavy influx of requirements and demands and a kind of crescendo of other activity marked by a number of successes as well as some failures. Requirements on AMC originate from a variety of sources.

There are those directive in nature, originating at DA or DOD or from command elements of AMC. Requests and requirements for inputs and assistance come from the CDC in connection with their efforts.

Also, requirements are generated largely in-house within AMC either as they are believed to be fruitful to the overall activity or in response to the formal system established for tradeoff investigation and cost-effectiveness demonstration.

Chart 6 lists examples of some of the more prominent efforts directed upon AMC from higher authority. I realize that some of these may not look impressive or may even seem picayune in the general standard of normality; cost-effectiveness of sandbag textiles is one such example. It's rather astonishing to realize, however, that the Army buys about 12 million sandbags a month–at about 30 cents a crack–for a total expenditure of well over $40 million a year, transportation included, which of course, extends for year after year in a situation such as Vietnam. As the list extends you get a feeling for the scope and variety. These requirements have arrived through a multiplicity of origins which include ACSFOR, CRD, DCSLOG, the assistant chief of staff for communications-electronics, and the COA.

DA DIRECTED EFFORTS

SGL VS TWIN ENGINE TROOP HELICOPTER C/E STUDY.

MBT-M60/S COMPARATIVE EVAL.

C/E OF SANDBAG TEXTILES.

C/E COMPARISON OF 1 1/4 TON TRUCKS.

CONTAINERIZED FREIGHT COST - PERFORM. ANAL.

REVAL - WHEELS

MBT SEC ARM. STUDY.

C/E OF GAS TO DIESEL CONVERSION, M113.

SAM-D DCP

VRFWS - DCP

Chart 6

DA DIRECTED EFFORTS (CONTINUED)

TACSATCOM C/E STUDY.

MICV-70 PD/CE STUDY.

REDLEG OPTIMUM MIX.

MBT-70 COMPANION VEHICLE STUDY.

AH-56A IN MID-INTENSITY ENVIRONMENT.

HUEY-TUG C/E ANALYSIS - ECO PROPOSAL.

ANALYSIS OF FIRE-DAMAGE MINIMIZATION, COMB. VEH.

MBT PRODUCEABILITY-COST REDUCTION STUDY.

POP-UP MINE AND BARRIER EQUIP. C/E ANALYSIS.

ARMY TACT. COMM. SYSTEM C/E ANALYSIS

Chart 6. Continued

Chart 7 represents various major CDC efforts to which AMC has been called upon to provide rather substantial input. As a general rule AMC is called upon to provide most, if not all, cost data; vulnerability, casualty and weapon kill criteria; and a variety of characteristic and performance information for both existing and developmental items of materiel.

INPUT ROLE TO CDC

MBT SEC. ARMAMENT STUDY.

SPECIAL FORCES AIRCRAFT C/E STUDY.

MICV-70 C/E (QMR) STUDY.

SAM WEPS. /SAMDEP.

VRFWS STUDY.

LEGAL MIX STUDY.

AAFSS.

FAMECE (ENG. CONST EQUIP) C/E STUDY.

[illegible]E C/E STUDY

TACFIRE

NON-NUCLEAR AMMO. STUDY.

HARD POINT TARGET WPN SYST. STUDY.

UTTAS

IRUS

TATAWS

Chart 7

The list continues to grow extensively when we consider those which have been in-house directed or initiated. Here I have separated the individual efforts out as representative of those which the systems and cost analysis division of the headquarters has either performed or played a reasonably substantial contributory role.

AMC IN-HOUSE EFFORTS

- COMPARATIVE ANALYSIS OF PTT 108/122.
- C/E OF RIFLE GRENADE LAUNCHING SYSTEMS.
- BALL PROPELLANT - SOURCE AVAIL VS. COST COMPARISON.
- COMPARATIVE ANALYSIS OF 5 TON TRUCK ENGINES.
- MARS II ECONOMIC BREAK - EVEN ANALYSIS.
- XM705/715 TRUCK COMPARATIVE ANALYSIS.
- COST BENEFIT OF H-19, CH-37 GROUNDING.
- DEFINITION OF FIGHTER/TRANSPORT ATTRIBUTES-MICV.
- NON-FATAL CASUALTY COST STUDY.
- ANALYSIS OF WEIGHT VS EFFECT. OF THE SOLDIER.

Chart 8

This presents examples of those which have been accomplished by the commodity commands, project managers and the AMSAA. I would like to reemphasize that this relatively brief list is representative only and by no means exhibits all or even a fair percentage of the total effort involved.

AMC IN-HOUSE EFFORTS (CONTINUED)

- C/E OF TACTICAL VEHICLES (WHEELS VS. TRACKS)
- MALLARD C/E METHODOLOGY
- ARSV PD/CE STUDY
- ATARS COST-PERFORMANCE ANALYSIS
- C/E OF AN/TPQ-28 (360° LOCATOR)
- SERGEANT - C/E NON NUCLEAR RQMT
- XM-179 SP-ARTY PD/CE STUDY
- C/E OF HELMETS
- C/E OF RADINAL PLY VS. COV. TIRES
- MBT COMPANION VEH. STUDY
- C/E METHODOLOGY-WHEELS VS TRACKS
- EVAL. SEA NITEOPS EQUIPMENT

Chart 9

In addition to those direct activities for studies and analyses, which must be considered the normal pursuits of systems analysis, we have also not been idle in attacking the whole problem of trying to bring some measure of structural and managerial formality into the overall activity.

We have also managed to establish at least the nucleus of a systems analysis group at each of the commodity commands and have provided for their location as independent entities outside the purview of any functional control to varying degrees of success at the moment.

ADMIN & MGMT OF AMC IN-HOUSE EFFORT

1. ESTABLISHMENT & DEVELOPMENT OF SAG'S
2. INSTITUTED & CONDUCTED THE MSRC PROCESS
3. ESTABLISHED THE BODY OF REGULATORY MATERIAL -- AMCR'S -- CMD DIRECTIVES
4. INITIATED & PUBLISHED THE AMC COST ANALYSIS HANDBOOK.
5. INTRODUCED A MONTHLY EXCHANGE -- "CAME"
6. INITIATED AMC DATA BASE -- COST & PERFORMANCE.
7. ESTABLISHED & ADMIN. AMC "QUICK-REACTION" SA CONTRACT.
8. PREPARED THE AMC TECH MANUAL -- "CATEM".
9. INITIATED AUTOMATED ABSTRACT SYSTEM FOR STUDIES.

Chart 10

The materiel studies review committee process has been installed and is a going concern to provide a high-level review of selected AMC studies and products. We have a fair start on a governing body of material, which is both accepted and acceptable. A cost analysis handbook has been published for AMC-wide use, and a monthly periodical covering both systems and cost analysis events and activities is in widespread general use.

We have initiated the AMC data base for both cost and performance values on materiel and administer the AMC quick-reaction contract that has provided many project managers with analytical answers to problems on short notice. The AMC Manual on Techniques and Methods is well underway and nearing completion, and an automated system on abstracts of completed studies has been started.

An identifying and locating scheme for all developed and available models and methodologies has just recently been undertaken. This overall effort is designed to reduce the number of times it may be necessary to reinvent the wheel. We have further introduced the AMSAA-SAG meetings as regular events and have prepared the two command PCR's for systems and cost analysis. Here, our record stands only at 50 percent, and I am sorry to announce that the systems analysis PCR will not be acted upon for FY 70, We have, however, been promised consideration on the next cycle and possibly our luck will be better in FY71.

Our big accomplishment of this year was the formal establishment of the AMSAA, and although the Table of Distribution (TD) for this organization is not yet finally approved, enough provisional and interim authority exists to permit counting this activity as now firmly established. Additionally, an index of CER's regardless of source, and their abstracts is well on the way to development; AMC contributed almost half the papers accepted by the last Army Operations Research symposium; we have heavy participation in the forthcoming DOD cost research symposium and, of course, we have established SAS-69.

ADMIN & MGMT OF AMC IN-HOUSE EFFORT (CONTINUED)

10. ESTABLISHING COMPENDIUM OF MODELS & METHODOLOGIES.
11. INTRODUCED THE AMSAA-SAG MEETINGS.
12. PREPARED CMD. PCR's FOR SA, CA.
13. ESTABLISHED AMSAA FORMALLY.
14. PREPARING SUMMARIZED INDEX OF CER's.
15. REPRESENTATION IN ARMY OR SYMPOSIUM.
16. PARTICIPATION IN DOD COST RESEARCH SYMPOSIUM.
17. SAS-69

Chart 11

As long as we're on the subject, I may as well expose some of the things that have been done in the field operating cost area, either as contributed to or performed directly for the Army's field operating cost agency.

The analysis of weapon system operating costs is, at the moment, a fairly active project, but O&M costing of Army aircraft is not doing too well. Primarily, this is a result of the capability available and the continuing pressure of higher priority assignments (AAFSS, HUEY-TUG and UTTAS to mention just a few).

All of the others shown have been completed and were full blown studies in their own right. The costing for major Combat Development Command (CDC) studies, of necessity, had to include field operating costs - collected and developed by AMC. We could also add SAMWEPS, SAM-D and a number of others to this list.

Finally, AMC has primary participation in the DOD life cycle cost program for procurement largely a consideration of field operating costs with the balance related to AMC inhouse logistic costs and requirements. As you know, AMC has no direct responsibility or authority over operating costs within the field forces—or the 2000 program.

FIELD OPERATING COST EFFORTS

- ANALYSIS OF WEAPON SYST. OPERATING COSTS.
  - O&M COST OF ARMY AIRCRAFT
    - NUCLEAR AMMO COST STUDY.
      - O&M COST OF FOOD SVC OPNS.
        - AMMO STOCKPILE O&M COST (AND COST OF DEPOT OPNS)
          - M551 - SHERIDAN COST STUDY
            - O&M DATA BASES FROM AMC INPUTS TO:
              - TATAWS
                - AAFSS
                  - DIV ARTY MIX
                    - REVAL WHEELS
                      - MBT-70 - STUDIES.
- ARMY PARTICIPATION IN DOD LCC PROG FOR PROCUREMENT

Chart 12

What does the future hold, and what might it look like for systems analysis in AMC? Well, certainly if the past is any acceptable base for prognostication and if the techniques of forecasting are valid, the future has got to look something like this. The difficulty enters in the relationship of our capability to meet the chall. upon numbers alone, AMC's formal inhouse capability would plot-out about the way the chart shows. The first dip on the left side of the curve corresponds to the freeze and cut-back of December 1967. Things then thawed out some; the step up is supposed to represent approval of the TD for AMSAA and go ahead on that basis. Thereafter, about all we can expect is a level function continuing through 1969 and 1970, corresponding to the current state of our PCR. Where a break upward in the curve may then occur is, of course, anybody's guess. The time markers on the bottom of the chart represent the beginning of calendar years. In cost analysis things look a bit better.

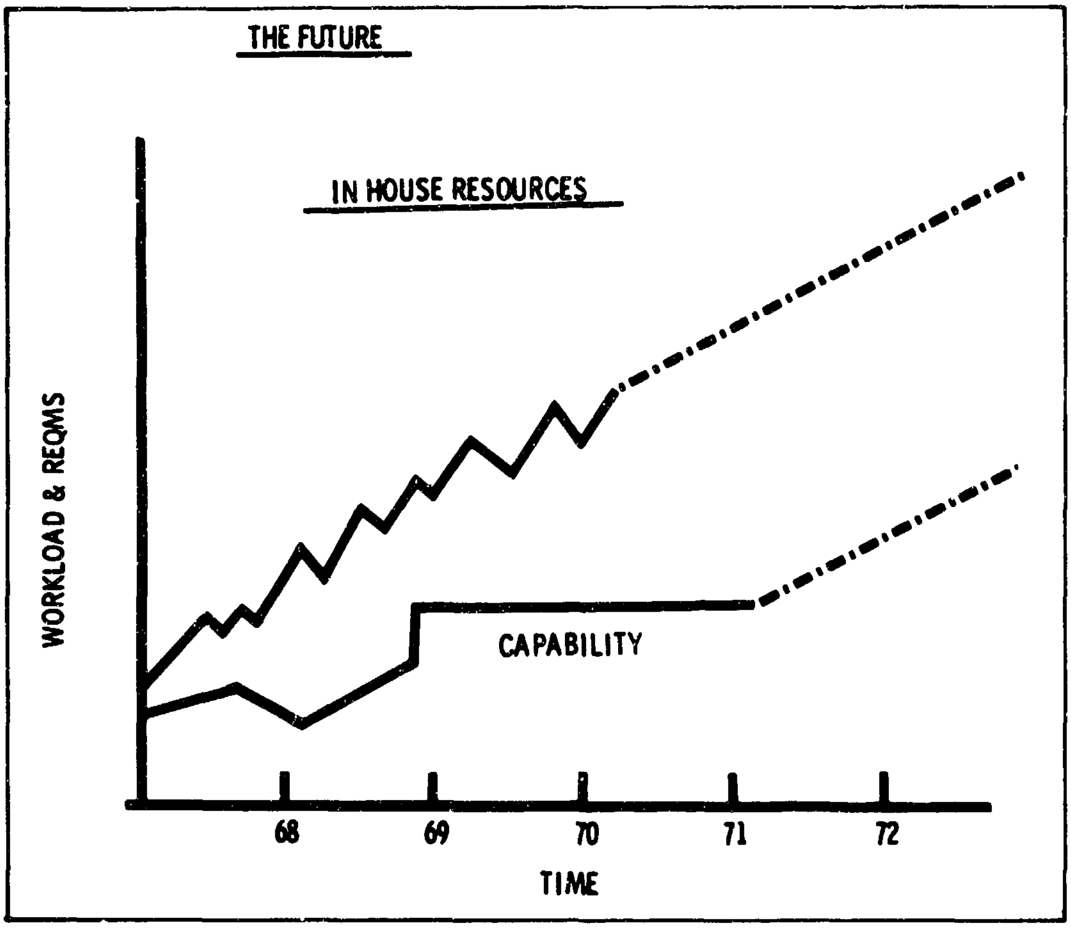


Chart 13

The command received the bulk of its personnel space allotment in July and October of 1968 (shown by the solid line), and the way we filled to this authorization is shown by the broken line. Actually, we were in an over-hire position for some time before receipt of the initial increment in July of 1967. I believe, thereafter, we made good progress toward filling to ceiling considering an area which is clearly a seller's market. The idea, of course, is to push the end point of the broken line up to that authorized. I suspect, however, that this gap will be a difficult one to completely eliminate–turnover, recruitment, and the lead time for processing in the personnel system being what they are.

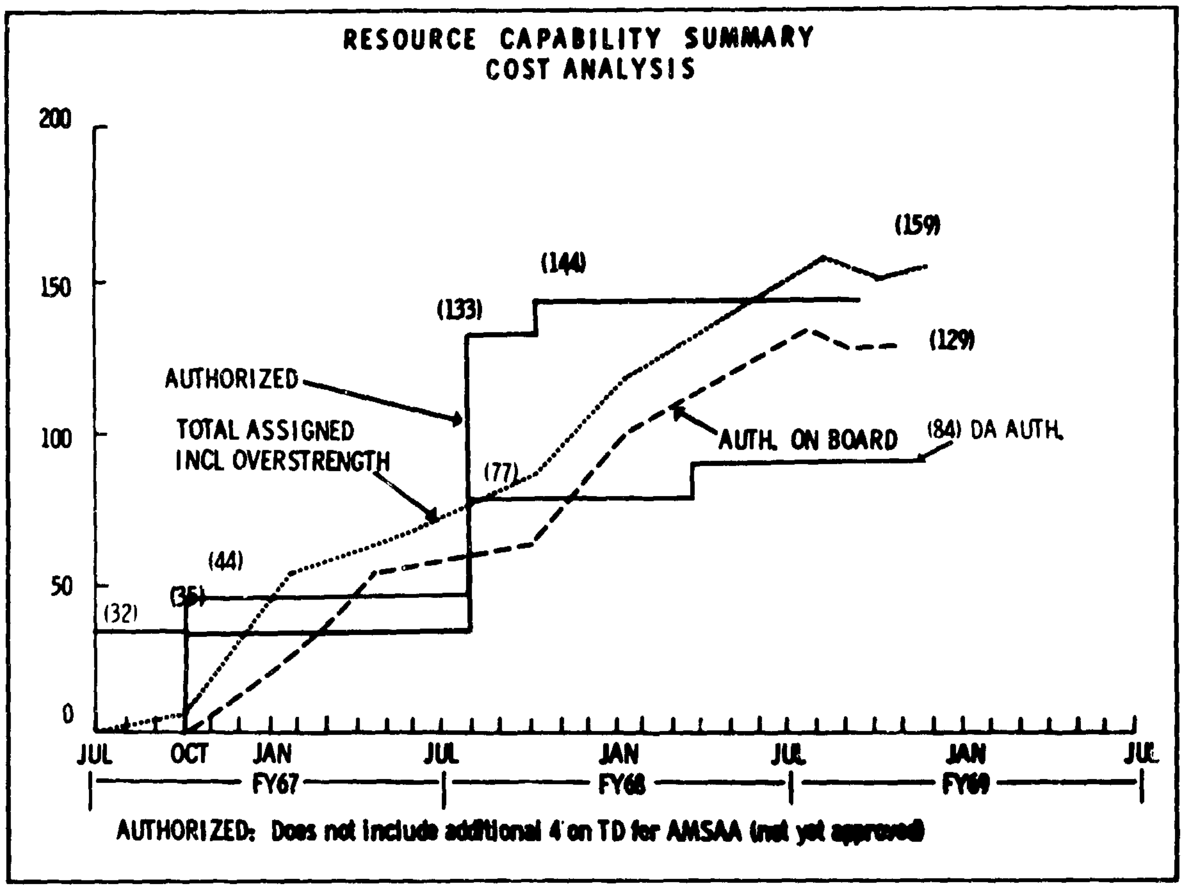


Chart 14

This chart still does not tell the whole story, since cost analvsis has been an area of heavy augmentation in AMC. The dotted line indicates the total number of personnel assigned, committed and actually working in the area. The 144 spaces are distributed among the seven commands, the AMSAA and the headquarters; the smallest contingent is 5; the largest, 27. The systems and cost analysis division has 11 professional civilians in cost analysis, 14 in systems analysis, and 2 professional military officers. This force is augmented by a number of young military on obligatory tour, several typist trainees, and one WAC.

The next largest cost analysis capability in the Army is within Department of the Army. It is anticipated that both of the authorized lines shown will remain as level extensions maximum, at least through the remainder of FY69. The dice aren't really loaded – they're just a little flat on one side.

That's where we've been, what we've done, and a very broad prognostication for the future. The last point I'm supposed to touch on is what should AMC be doing. It is a rather formidable subject and should be the tone for roughly 60 percent of this symposium. There are, however, about four main topics which are repeatedly being singled out for comment concerning the way the studies we do are beginning to look as they appear on the desks of decisionmakers. I think that a little attention, or perhaps even standardization, in these particular areas may well produce a sort of instant return if diligently applied.

1. The first of these is related to what the decisionmaker should first see in a study after he gets by the cast of characters and the index. It's maintained that his route to a *clear statement of the objective* (a statement *of the assumptions which have been made*) establishes a section of fundamental understanding on just how these assumptions may interact with or impact upon the results obtained. We can hypothesize that the decisionmaker has been provided one distinct advantage. He has the option of either laying the volume down as being outside the realm of validity and his own experience of requirements for real world solutions or considering it worthy of further investigation and reading on. Practically all studies hold these ingredients but under varying degrees of diffusion and disclosure.

2. The second area of interest relates to sheer bulk alone. This apparently was the year for big studies, although it's obvious that size is primarily related to the sophistication and completeness sought and the needs of an adequate defense. On the other hand, we seem fair on the way to approaching the point where our decisionmakers will content themselves with a general feel for the texture of the binding and a rough idea of weight. If the dictates of sophistication and size continue to increase in proportion, one possible way out of this dilemma seems to be to relegate all tables of data (and the details of calculations with their justifying analyses) to appendices. The end analysis and values will be established in the body in that depth necessary to ensure flow of the analysis through its logical sequence. We could suppose that a good study, ideally, might consist of no more than about 25 pages in this fashion and yet cover all of the salient and pertinent features including the results and conclusions. Appropriate notations in the body of the analysis would provide easy access by the reader, to the details of the appendix should he be so motivated through either interest or disbelief.

3. The last two areas are sort of intermixed together and concern what I choose to call "better schemes for the integration of cost and effectiveness values" *and* the "presentation of results." Most of our studies tend to go through many pages of narration and analysis oriented exclusively to the effectiveness measure and somewhere near the back and almost as an afterthought--a table says "By the way, here are some cost numbers you can look at too." I think a great deal can be done by way of integrating the results. We can probably save the decisionmaker the task of having to perform such a mental balancing act and pick up a few points in the bargain. The corollary of presentation of the results should be similarly treated--using graphics always offers a neat way of presenting complex and variable results. As analysts we should be able to give the decisionmaker opportunities to quickly and accurately vary at least some of the values and perform his own private sensitivity analyses. As a bare minimum we certainly owe him some registration upon the plausible range of values and their impact.

I think I can best serve up a demonstration of these thoughts through a rather simple example.

Imagine, if you will, a situation where the analyst has managed to make some kind of quantification of effectiveness and cost for a series of different options, and to some equivalent base. The axes represent the cost to the enemy and the cost to us, respectively. The T over C ratio, of course, yields the absolute ranking in terms of targets destroyed per unit damage suffered (or cost) for each of the definitive points of concern. The idea is simple enough; it's acceptable, certainly, but unfortunately it may very possibly leave a major share of the story untold.

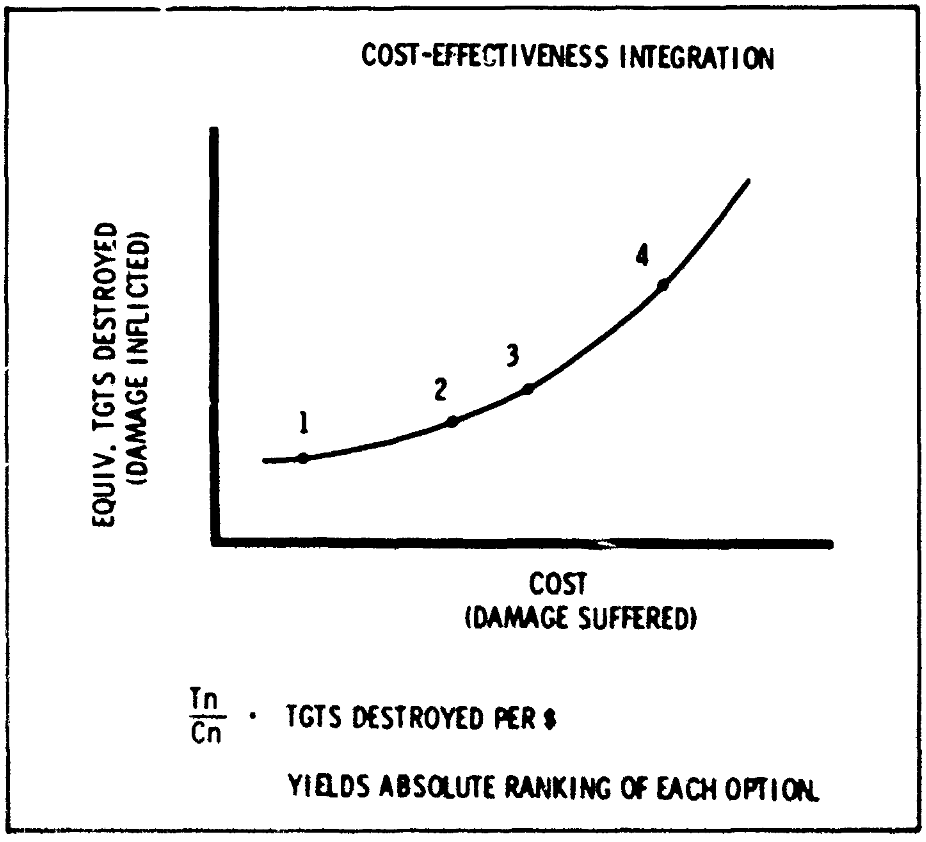


Chart 15

Let me redraw the picture, expand it to a slightly different case, and further hypothesize that (for this situation) some minimum level of destruction exists below which the job desired just will not get done, to the level required. We show a band here to represent that boundary as well as to let the decisionmaker know that *we are willing to* risk that a reasonable value would lie somewhere between the extremes. In this case, although two may have the higher absolute ranking, it lies outside acceptable limits, and we have constrained the case to a consideration of 3, which is marginal because it lies close to the lower extreme of the bank, and higher numbered options. Should the decisionmaker not *like* our choice of boundaries, we have at least laid out for him all the basic features for making his own choices and done it with a minimum of difficulty.

If we can carry this a step further, we should be able to define a maximum acceptable level of cost to ourselves. Again we band the values to indicate that some uncertainty exists. Please remember that the bands need not be straight vertical and horizontal lines but may, in fact, be something else if worked out to a bit more sophistication. Also, please do not hold me to scale in any of these drawings. In any event, the range of choices have been further limited: 5 is better than 4 but lies outside the acceptable range of choice. We have, in this example, now limited the decisionmaker to only two possibles, both of which are marginal. We have now put the man in a real box. If he chooses 3, the G3 will get mad; if he picks 4, the comptroller will probably quit.

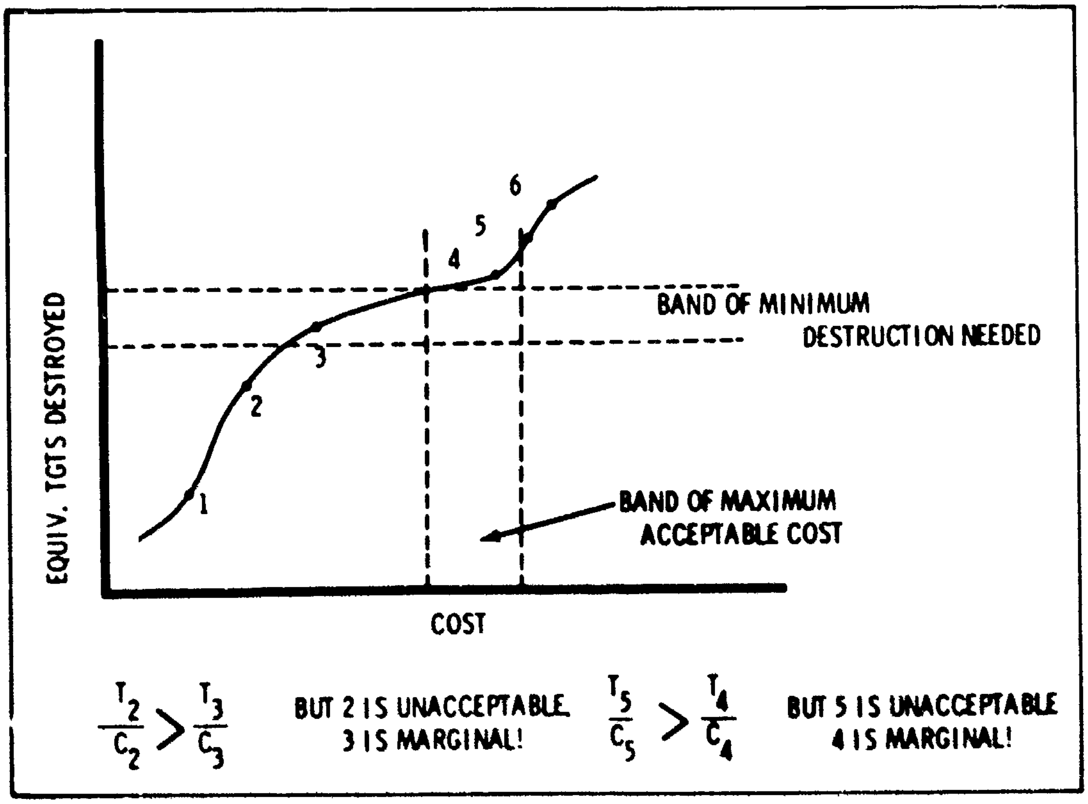


Chart 16

Let me leave our decisionmaker staring at a point half way up the wall for the moment, and look at something else that might be done to help the situation.

The first thing that suggests itself is that we look at other representations of *cost* on the same equivalent basis as used in the preceding chart. If we assume the cost associated with the black line represents the cost of the loss to us to inflict the damage shown, then perhaps we should consider the life cycle peacetime costs for the forces associated with each of the options. This particular representation is shown in blue on the chart; note that the points move around laterally in some unsymmetrical fashion. The points in value now represent a measure of the peacetime costs associated with the damage inflicted as previously determined. The analysis could be extended to include consideration of the red items, which represent wartime life cycle costs, and which could easily be established for various levels of conflict duration. (The red points are not plotted on the drawing to avoid clutter and confusion.) We now have a series of T over C ranking ratios that can be set forth in a neat table, each value standing for the benefit-cost ratio of all the conditions of interest. Not only has the decisionmaker been given an expanded horizon for choice, but also any need to sum peacetime and wartime costs together has been avoided and we can keep the two distinctly separate and measurable.

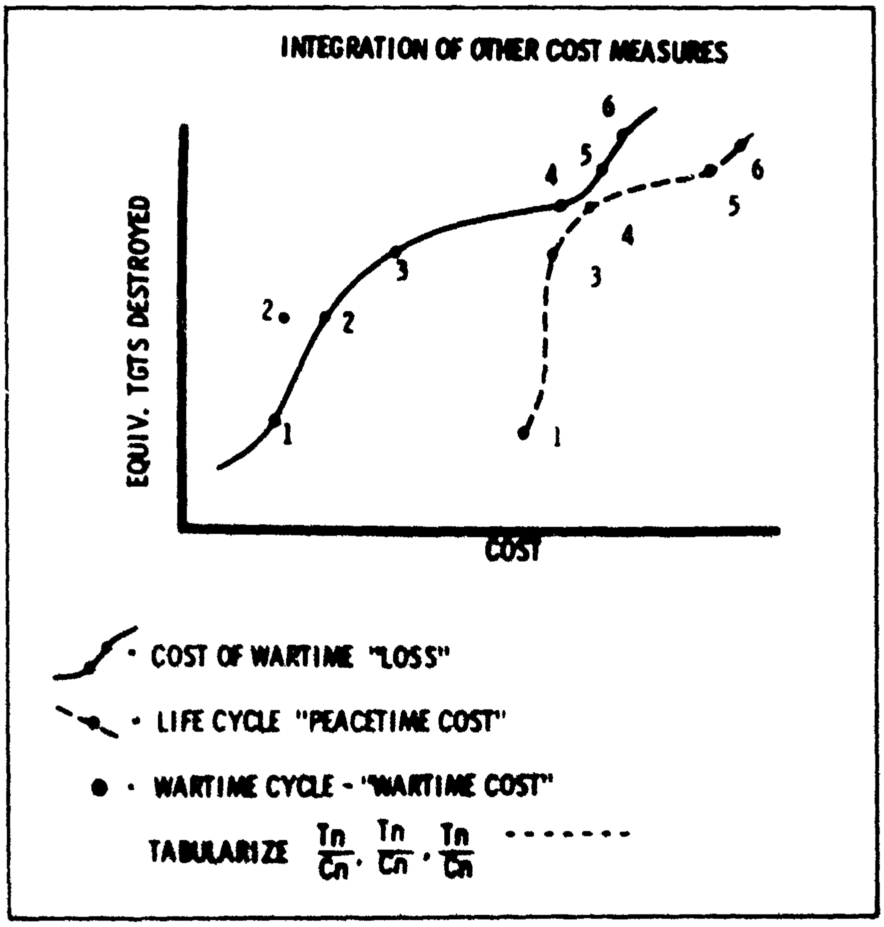


Chart 17

Should this still not help, and it's conceivable that all of the ratios could maintain either their same relative standings or exactly reverse in direct proportion, we have the option of another way to attack the problem. You are aware that our inhouse estimates or those of our contractors occasionally miss the mark by a number of points. In any case, cost estimates are only estimates and such have a definite area of uncertainty about them. This is not a point to be taken advantage of, but there is heavy and increasing pressure that costs which are indeed uncertain be specified in terms of some uncertainty boundaries. The point is especially appropriate for estimates made on paper systems; the more paper the system, the more uncertain the estimate turns out to be.

Chart 18 shows option 4 taken from the old example, assumed as a paper system, with the costs carried out over various quantities as an uncertainty band and represented by the optimistic and pessimistic extremes.

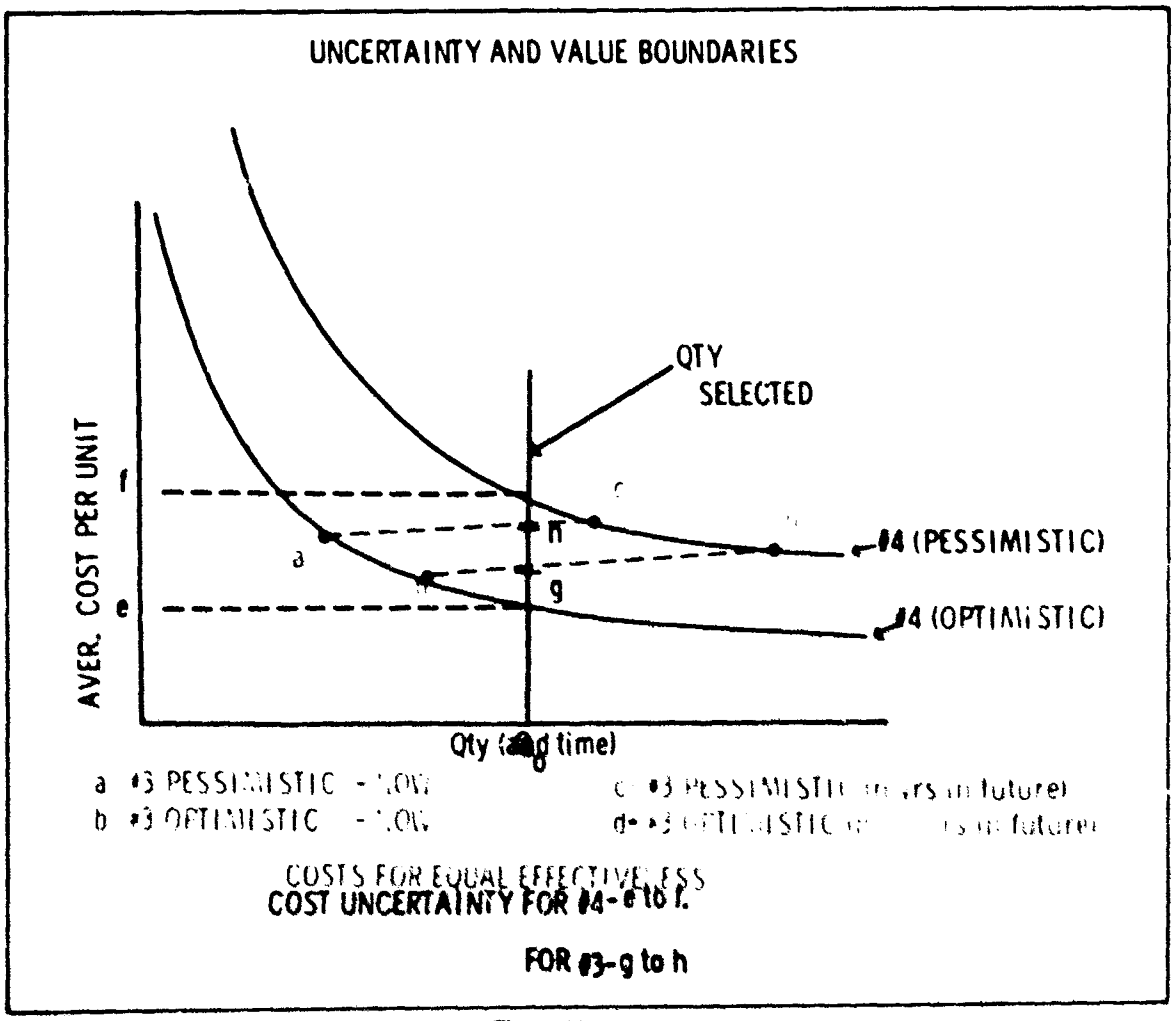


Chart 18

I'll further assume that option 3 represents a current system or one close to production and that both optimistic and pessimistic values for option 3 can be located on the lower boundary of option 4. These values, A and B on the chart, can now be extended over the requisite time period necessary to meet the pessimistic boundary of option 4, which is based upon whatever time dependent escalation factor we decide to choose. The polygon between the lettered points now describes the possible cost values for both options under the existing uncertainty. Corresponding cost values for equal effectiveness, as shown on the chart, are not strictly necessary, but it may be required to choose a multiple of the lower cost option in order to get the lines to meet.

If I now decide how many of these I need (either on some equivalent basis or independently) I can fix the expected spread of uncertainty for each. In this case option 3 goes from G to H; the value spread for option 4 lies between E and F.

With these values I can now go back to the original dilemma and use them as additional analysis for the decision required. Although a value judgment in choice is up to our decisionmaker, we can take pride in that all of the values have been presented, including their extremes in a manner which is easily assimilated and permits both the application of judgment and some variability.

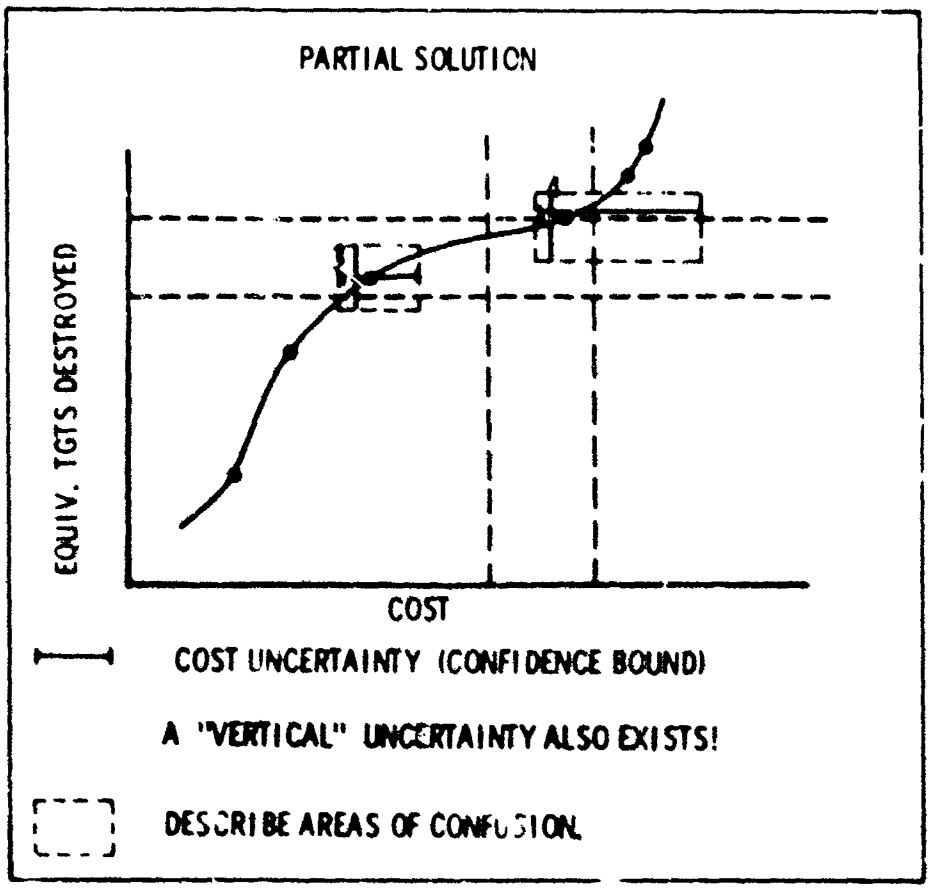
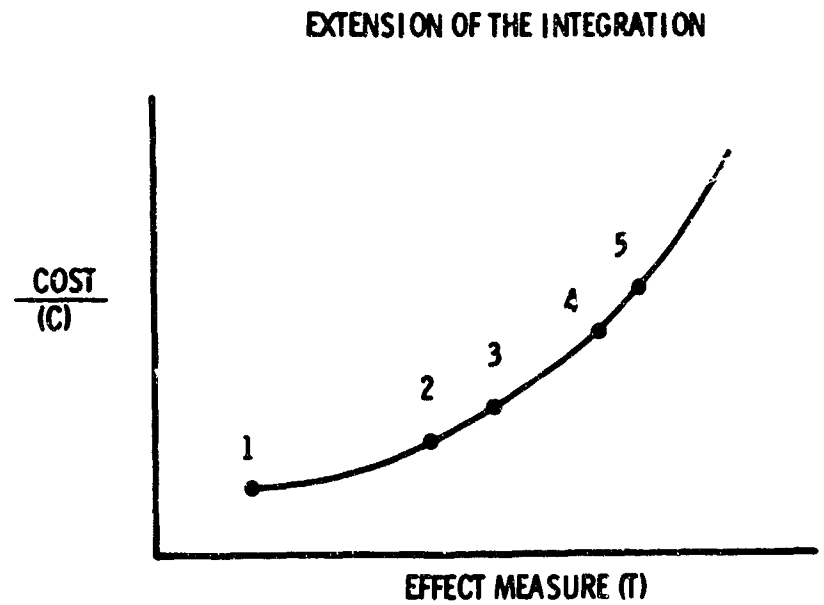


Chart 19

We have, therefore, provided our decisionmaker with all of the ingredients analytically feasible for this phase of the problem. He has been provided with some inherent limited capability to vary the values in accordance with his own dictates and, moreover, we have managed to present this part of the results to him succinctly and through the use of no more than one page.

In addition to the schemes discussed here there are, of course, others with equal, if not even better, applicability. The techniques of marginal analysis are always in favor and can easily be applied either independently or in concert with others. The economist's concept of elasticity also offers promise in certain selected instances where a variety of quantifying measures and ranges may be a desirable condition for choice. The techniques used are immaterial; the objective is to perform the best possible analytical integration of results and present them in as concise, complete and yet summarized form as possible.



WANT MEASURE OF VARIABILITY OF CHANGE.
DEFINE:

$$\text{"ELASTICITY OF C/E"} = \frac{T_{n+1} - T_n}{T_{n+1} + T_n} \Bigg/ \frac{C_{n+1} - C_n}{C_{n+1} + C_n}$$

Chart 20

In summary, the current areas of most concern lie at the very beginning of our studies and at the very end. The objective is to pay these immediate and critical attention; they have an extremely high potential pay-off value and the promise of extensive return. The many other aspects of our studies and analyses that occur between these two extremes (depicted by the wiggly lines on the chart) are also critical and worthy of our attention. Under the theory that all things cannot be attended to at once however, dictates that we defer these for the moment, attend to them on the next cycle, and possibly make them headliners for SAS-70.

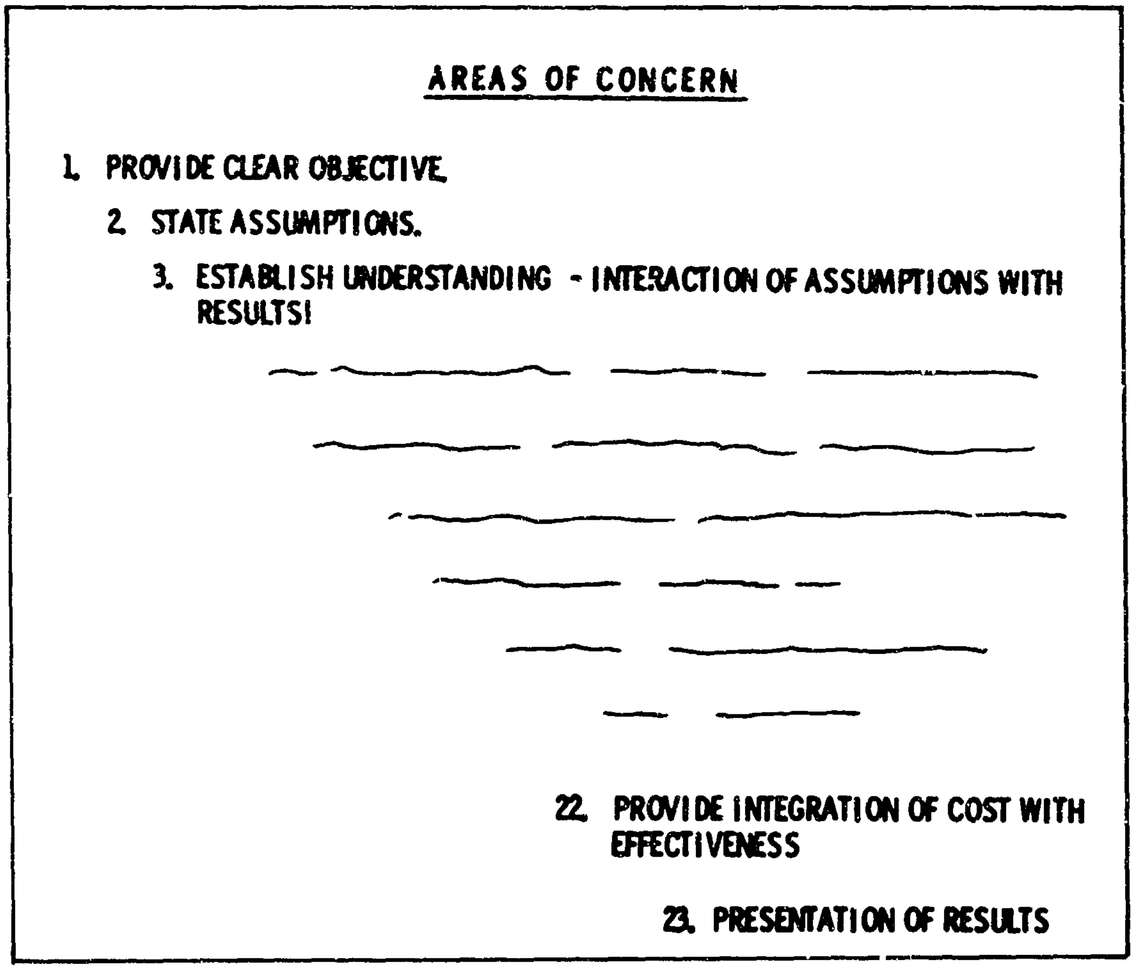


Chart 21

ORGANIZATION AND FUNCTIONS OF THE ARMY MATERIEL SYSTEMS ANALYSIS AGENCY

Dr. Joseph Sperrazza
Director of the Army Materiel Systems Analysis Agency
U.S. Army Materiel Command

The Army Materiel Systems Analysis Agency is an off-shoot of the old Weapon Systems Laboratory. Formerly a part of the Ballistic Research Laboratories (Chart 1) legally we have been an Army provisional organization since January 1968. We became de jure this November.

Chart 1

I'm going to give you a synopsis of the organization, its relations with other groups of the Army Materiel Command complex, and its relationships with agencies outside the Army Materiel Command complex. I shall also mention some on-going tasks and point out where some of these must be carried out on joint bases with other groups.

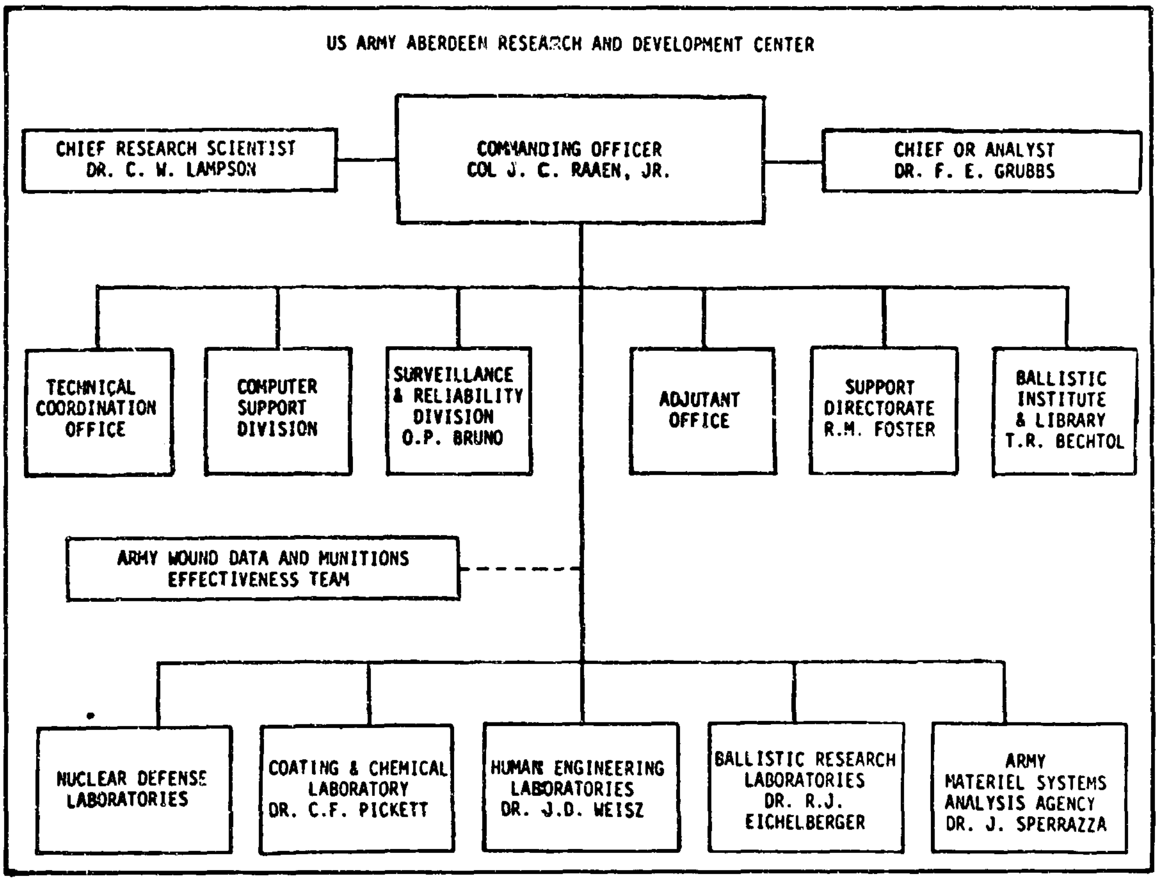


Chart 2

AMSAA, the acronym for the Army Materiel Systems Analysis Agency, is part of the US Aberdeen Research and Development Center. This center is a Class II activity tenanted at Aberdeen Proving Ground but reports directly to AMC headquarters.

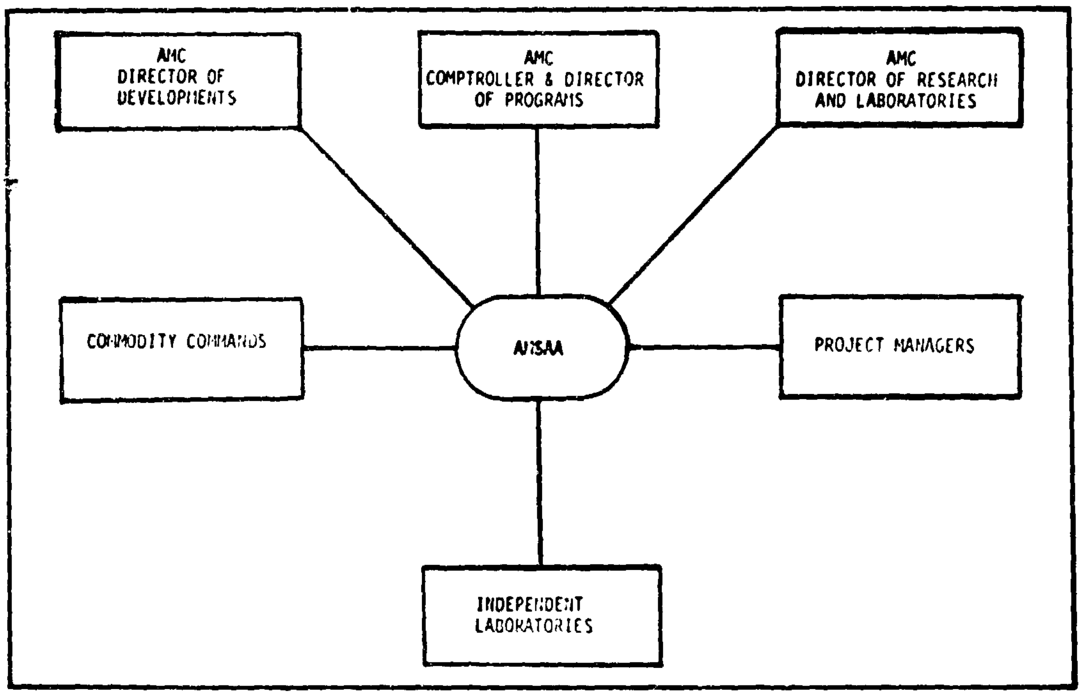


Chart 3

We touch base with many AMC Groups. Organization control rests with Directorate of Research and Laboratories. Funding for the most part is provided by the Directorate of Development and Engineering. Priorities and overall purview of the overall cost analysis studies rests with the Comptroller and Directorate of Programs. Tasks are assigned to us by all three of these directorates. Moreover, we are tasked by the Project Managers and Commodity Commands. During the course of carrying out our studies we recognize that many crucial data inputs either are missing or not firm enough and, therefore, we try to influence the so called "independent" laboratories of the AMC to generate these inputs.

Historically, our expertise has been predominately in the field of weapons effectiveness; that is, primarily in the field of firepower. General Bunker has recognized that this area is too restricted, and he insisted that we broaden our base and become involved in all areas of materiel, including such significant items as vehicles, electronics and communications, and equipment for the infantrymen. In fact, as I will mention later, one of our studies is on developing a realistic cost-effectiveness model for evaluating infantry helmets.

I believe earlier Mr. Tropf alluded to AMC Regulation Number 70-28, which is on systems analysis. In that regulation each of the major commands of the AMC has been directed to set up a systems analysis group so as to support the requirements peculiar to that command. In chart 4, I list the commands plus two laboratories that I believe should set up systems analysis groups too. For example, in the field of infantry equipment, Natick needs to set up a viable systems analysis group. Likewise, I feel that Harry Diamond Laboratories

Systems Analysis needs boosting. The numbers in parenthesis in each of the rectangles indicates roughly the number of people in the systems analysis groups at the time I prepared the paper last month, but these numbers have changed somewhat since then. Many tasks, in order to be coherent and meaningful, ought to be done on joint AMC bases with headquarters, AMC, AMSAA and one or more of the commands or Laboratories. Some joint activities are presently underway.

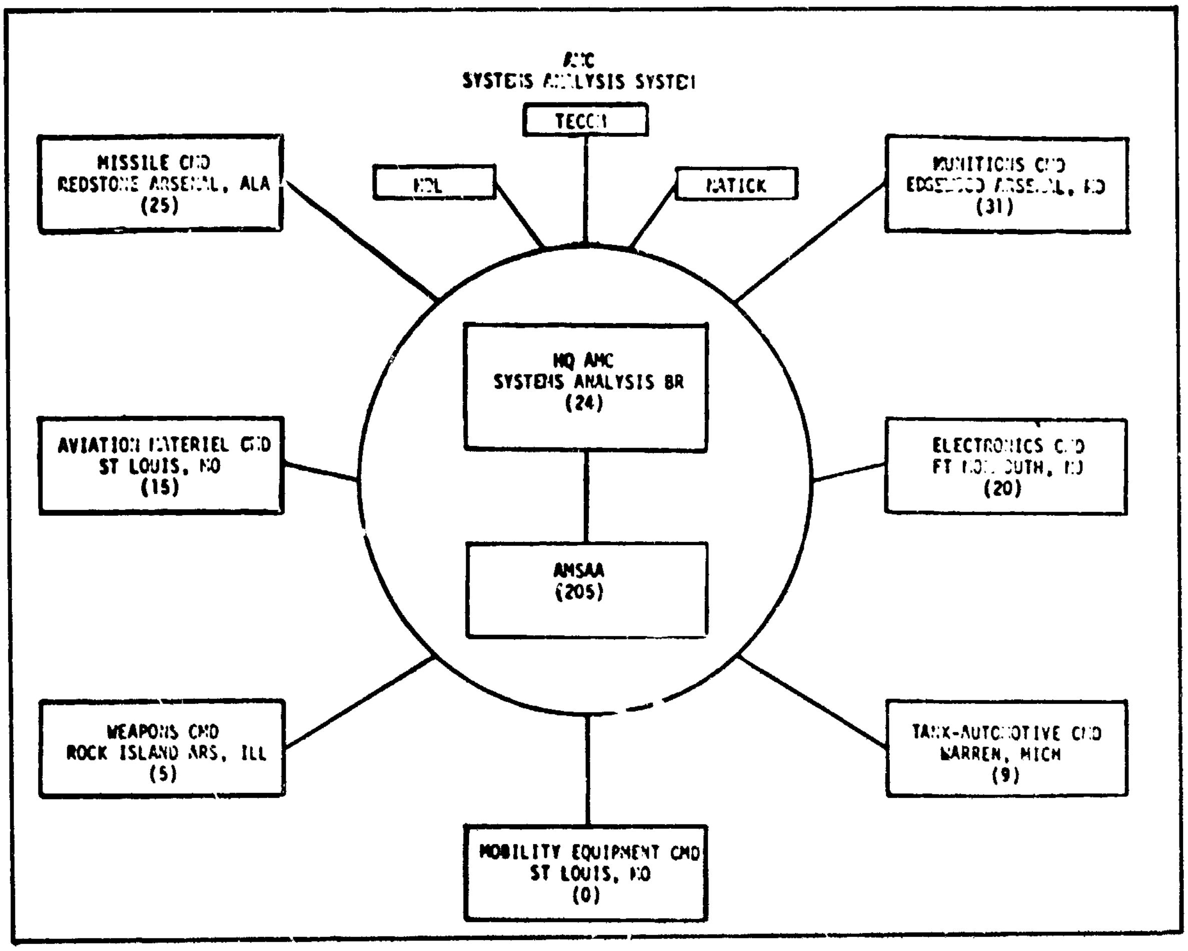


Chart 4

In fact, we have scheduled quarterly meetings of the systems analysis groups. The first kick-off meeting along these lines was held at AMSAA during July 1968; this first meeting set the stage for subsequent meetings. In September we held a 2-day meeting at Munitions Command. The first day was an expose of headquarters, MUCOM, and the various arsenals on their Research and Development activities. The second day was on procedures to implement closer ties among all of us. Next month is AVCOM's "Day in Court."

Officially, we are organized as shown on Chart 5. We are however, in the process of consolidating some of the activities and highlighting others. For example, methodology and cost will be combined; a new division on air warfare will be set up; maintainability and reliability will be highlighted and will enjoy the division status. For the moment, however, let me give you a finer breakout of the organization as it is presently constituted.

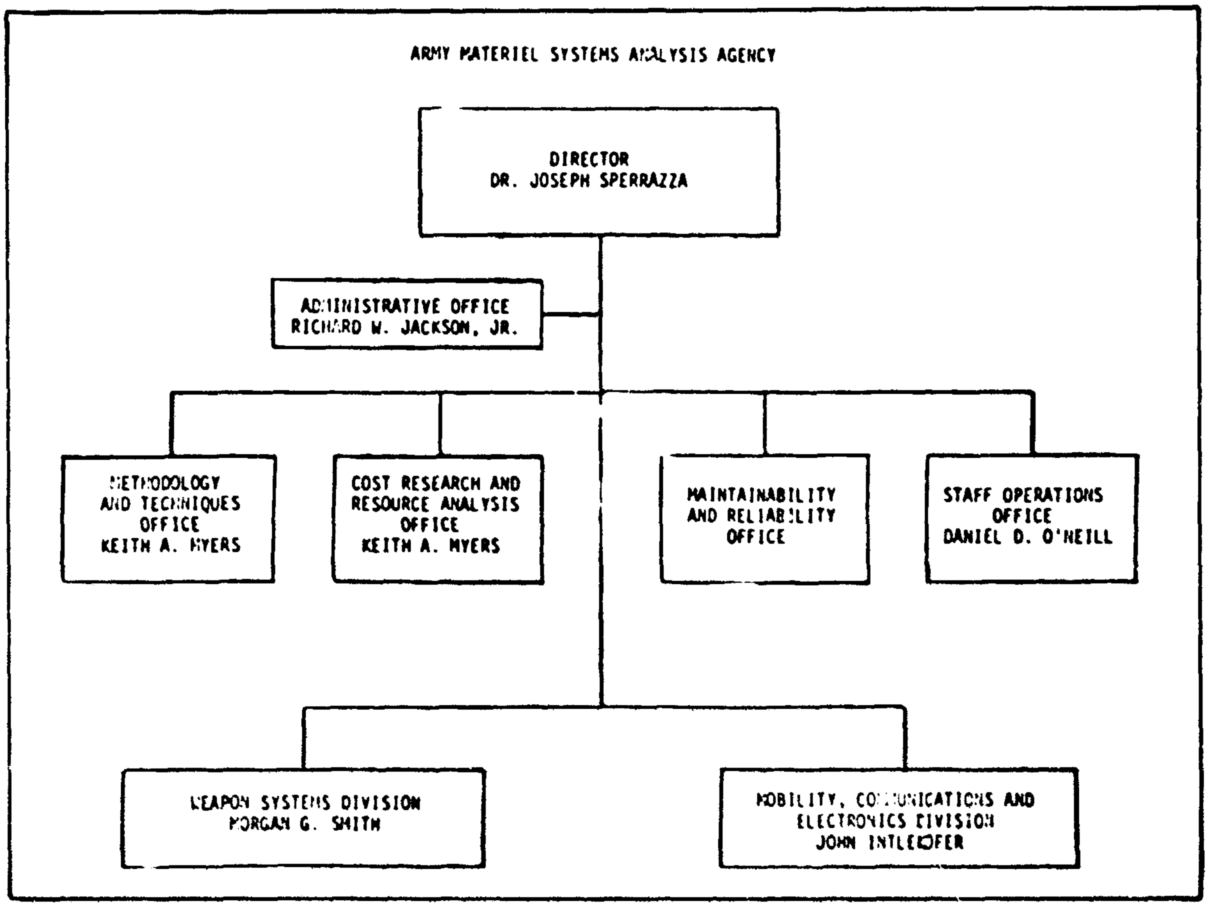


Chart 5

Of more importance, however, are the next series of charts which highlight some of the important tasks underway.

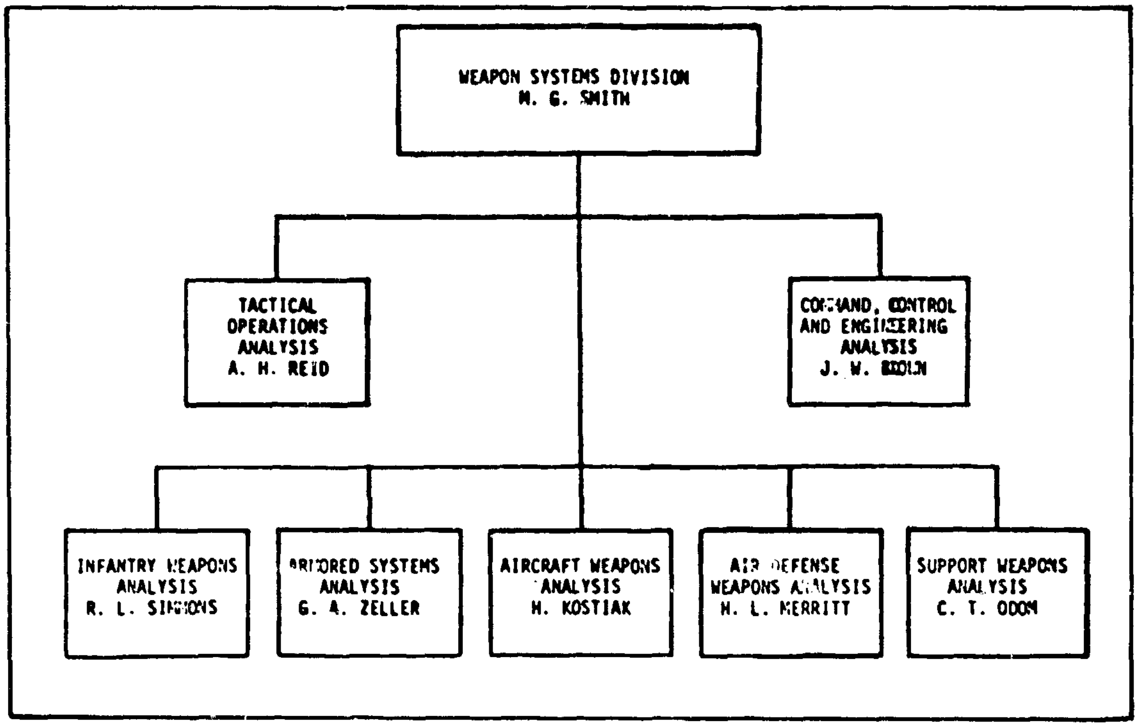


Chart 6

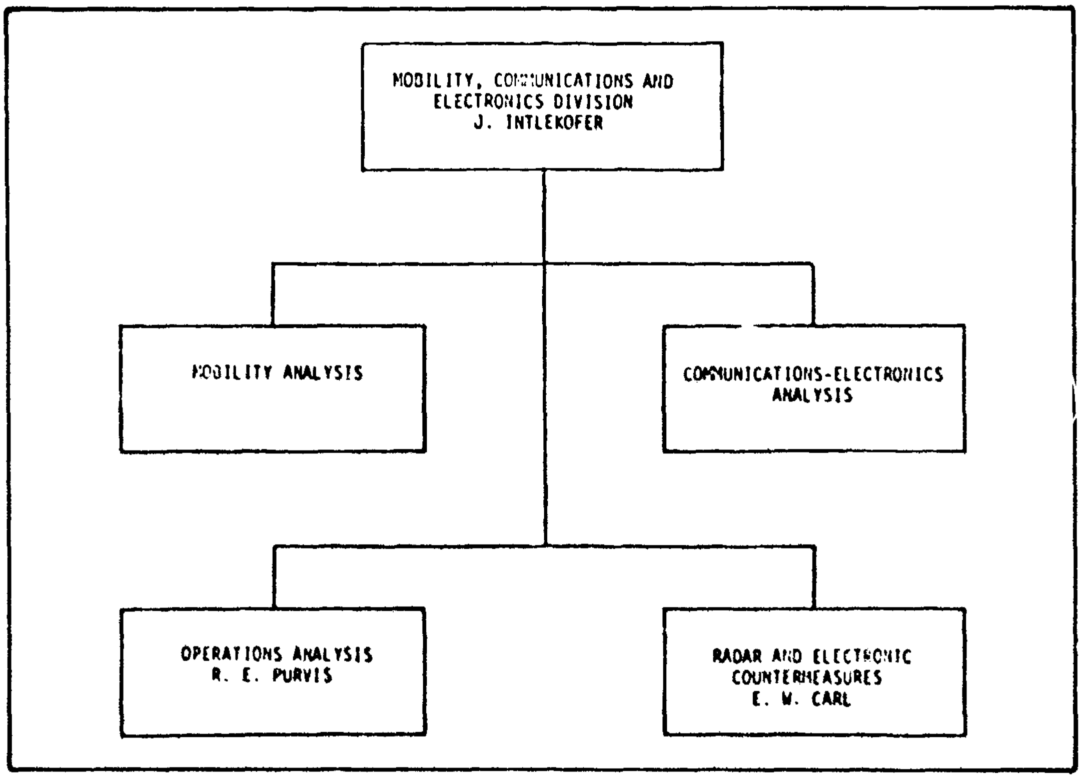


Chart 7

INFANTRY WEAPONS ANALYSIS

PERFORMANCE DATA BASE FOR ARMY WEAPON SYSTEMS	(AMC)
MORTAR FUZE COST-EFFECTIVENESS STUDY	(MUCOM & HDL)
ARMY SMALL ARMS PROGRAM	(WECOM)
SUPPORTING RESEARCH - PISTOLS, RIFLES, MACHINE GUNS, GRENADE LAUNCHERS, ETC	
PERFORMANCE DATA BASE	
SYSTEM ANALYSIS OF SMALL ARMS	
CANISTER AND BEEHIVE EVALUATION	(MUCOM)
LETHALITY ASSESSMENT FOR SMALL ARMS, ANTITANK AND MORTAR WEAPONS	(MUCOM & WECOM)
FAE EVALUATION	(MUCOM)
BATTLEFIELD SURVEY FOR WOUND BALLISTICS VERIFICATION	(IN-HOUSE)

Chart 8

ARMORED SYSTEMS ANALYSIS

MBT-70/M-60 COMPARATIVE EVALUATION	PM-MBT-70, M67-70
ARSV (ARMORED RECONNAISSANCE SCOUT VEHICLE) PD/CE STUDY	PM-ARSV
VRFWS (VEHICLE RAPID FIRE WEAPON SYSTEM) SYSTEMS ANALYSIS	PM-VRF
105 APDS/HEAT COST-EFFECTIVENESS STUDY	(MUCOM)
MICV-70 (MECHANIZED INFANTRY COMBAT VEHICLE) PHASE III PD/CE STUDY	(TACOM)
TATAWS III (TANK, ANTI-TANK AND ASSAULT WEAPON SYSTEMS)	(CDC)
MBT-70 P/CR STUDY	PM-MBT-70
REPAIR OF COMBAT DAMAGE TO TANKS	IN-HOUSE

Chart 9

SUPPORT WEAPONS ANALYSIS	
HELMET COST-EFFECTIVENESS STUDY	(NATICK)
ARTILLERY PARAMETRIC DESIGN ANALYSIS	(MUCOM & WECOM)
COST-EFFECTIVENESS STUDY OF 105MM AMMUNITION	(MUCOM)
DIACBA CONCEPT EVALUATION STUDY	(MUCOM)
LETHALITY OF US AND FOREIGN AMMUNITION	(MUCOM)
IMPROVED ARTILLERY EVALUATION MODEL	(MICOM & WECOM)
LANCE WARHEAD SENSITIVITY ANALYSIS	(MICOM-PM)
EVALUATION OF BODY ARMOR	(AMC)
JMEM/SS	(JTCG/ME)

Chart 10

AIRCRAFT WEAPONS ANALYSIS

- VIETNAM AIRCRAFT COMBAT DATA ANALYSIS
  - AH-1G WEAPON STUDIES
  - C/E STUDY OF FIRE CONTROL SYSTEMS
  - AIR CUSHION VEHICLE WEAPON STUDY
- AIRCRAFT WEAPONIZATION EFFECTIVENESS STUDIES
  - REDEYE VS GROUND TARGETS
  - 2.75 INCH FLECHETTE ROCKET EVALUATION
  - 30MM AND 2.75 INCH ROCKET COMPARISON
  - AVROC (40MM AVIATION ROCKET)
  - TRACER STUDY

Chart 11

RADAR AND COMMUNICATIONS ANALYSIS	
MALLARD COMMUNICATIONS ANALYSIS	(ECOM)
TACTICAL COMMUNICATIONS EFFECTIVENESS	(ECOM)
COST-EFFECTIVENESS EVALUATION MODELS FOR COMMUNICATIONS SYSTEMS	(ECOM)
RADAR SYSTEM EFFECTIVENESS	(ECOM)
TRACKING RADAR ERROR MODELS	(AMC, ECOM)
SIMULATED RADAR RECEIVER MODELS	(ECOM)
SYSTEMS ANALYSIS OF ELECTRONIC COUNTERMEASURES	(ECOM)
RADAR CLUTTER STUDY	(AMC)

Chart 12

AIR DEFENSE ANALYSIS	
SURVIVABILITY OF TACTICAL SURVEILLANCE DRONE	(ECOM)
ANALYSIS OF FIRING ACCURACY AND TRACKING TESTS OF XM163 AND XM167	(TECOM & WECOM)
EVALUATION OF REDEYE AND CHAPARRAL LETHALITY	(MICOM)
SURVIVABILITY STUDIES OF US ARMY AIRCRAFT (LTTAS, UTTAS, AH-56A, ETC)	(AVCOM)
SAM-D STUDY EFFORT	(MICOM)
IMPROVED AIR DEFENSE EVALUATION METHODOLOGY	
PERFORMANCE DATA BASE FOR ARMY WEAPON SYSTEMS	(AMC)

Chart 13

TACTICAL OPERATIONS ANALYSIS	
LASER HAZARD STUDIES	(ECOM, MICOM, AVCOM, WECOM & TACOM)
RAP (ROCKET ASSISTED PROJECTILE) SAFETY HAZARD STUDY	(MUCOM)
US AND ENEMY TARGET ACQUISITION CAPABILITIES ANALYSIS	
THREAT AND OPERATIONAL ANALYSES DYNAMIC TARGET ARRAYS	
DYNAMIC ARMOR THREAT ANALYSES	(TACOM)
THREAT ANALYSIS FOR EVALUATION OF SECONDARY ROLE OF AIR DEFENSE CANNON	(WECOM)
SEA NITEOPS INTERFACE STUDIES	(ECOM)
WDMET SCENARIOS	

Chart 14

COMMAND, CONTROL AND ENGINEERING ANALYSIS	
LASER HAZARD STUDIES	(ECOM, MICOM, AVCOM, WECOM & TACOM)
TOW HELICOPTER SIMULATION	(AVCOM & MICOM)
SHERIDAN-SHILLELAGH SIMULATION	(TACOM)
CHAPARRAL AND REDEYE SIMULATION	(MICOM)
EVALUATION OF WESTINGHOUSE AND EMERSON FIRE CONTROL OR GUIDANCE TRACKERS	(MUCOM)

Chart 15

MOBILITY ANALYSIS	
FUTURE VEHICLE CAPABILITIES	(TACOM, AVCOM)
PHYSICAL AND PERFORMANCE CHARACTERISTICS FOR TACTICAL VEHICLES	(TACOM, AVCOM)
ANALYTICAL TECHNIQUES FOR DETERMINING VEHICLE PERFORMANCE AND COST-EFFECTIVENESS	(TACOM, AVCOM)
UTILITY TACTICAL TRANSPORT AIRCRAFT SYSTEM (UTTAS)	(AVCOM)
MBT-70/M-60 MOBILITY COMPARISON	(TACOM)
MICV-70 TRADE-OFF ANALYSIS	(AMC)
1-1/4 TON TRUCK STUDY	(AMC)
RADIAL VS CONVENTIONAL TIRE STUDY	(TACOM)
FOOD SERVICE FIELD FEEDING SYSTEMS OF ARMY UNITS	(NATICK)
SINGLE VS TWIN ENGINE HELICOPTER	(AMC)

Chart 16

METHODOLOGY	
DEGRADATION EFFECTS PROGRAM	
JOINT MUNITIONS EFFECTIVENESS MANUAL (SURFACE-TO-SURFACE AND AIR-TO-SURFACE)	
IMPROVED AIRCRAFT AVAILABILITY MODEL	(AVCOM)
SURVEY AND ANALYSIS OF AVAILABLE COMBAT EFFECTIVENESS MODEL	
IMPROVED LETHAL AREA MODEL	(MUCOM)
STUDY AND COMPARISON OF RANGE ESTIMATION ERRORS	(WECOM & TACOM)
DEVELOPMENT OF A STOCHASTIC TERRAIN MODEL	
SUPPORT OF AIR DEFENSE TASK FORCE	

Chart 17

COST ANALYSIS

COST AND EFFECTIVENESS ANALYSIS OF SANDBAGS

DEVELOPMENT OF COST ESTIMATING RELATIONSHIPS

DETERMINATION OF INTRA-THEATER LOGISTIC FUNDING

COST LIBRARY AND DATA BANK

COST OF NON-FATAL BATTLE CASUALTIES

GROUND VEHICLE COST MODEL

Chart 18

PRELIMINARY CONCEPTS FOR A TACTICAL LOGISTIC VEHICLE EVALUATION METHODOLOGY

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U.S. Army Materiel Command

In the short time allotted to me I am going to summarize for you the approach which our division of AMSAA is taking toward the measurement of effectiveness of tactical logistic vehicle (TLV) systems. I will discuss the philosophical basis for our approach and describe in broad terms some of our modeling efforts. Time will not allow a detailed treatment of our mathematical models.

The role of the logistics system is to permit combat commanders as wide a freedom of choice in strategy and tactics that the tactical unit structure, the enemy situation, and the fighting environment such as terrain and weather, will allow. Stated in another way, an organization of tactical logistic vehicles is effective in the degree to which it minimizes the logistical constraints upon the tactical units. Some examples of constraints which may be placed upon a tactical combat organization by an inefficient logistics organization are limited maneuverability caused by fuel shortages or late deliveries, as well as limited firepower due to lateness or absence of ammunition deliveries. The effectiveness of the tactical logistic vehicle system, which is one major subsystem of the total logistics system, may be rated by the extent it prevents these constraints from occurring under a variety of combat conditions.

This view of TLV system effectiveness represents a significant departure from the effectiveness concepts employed in past and current evaluation efforts. The more traditional view has been that the effectiveness of a vehicle system could be isolated from the tactical unit structure and tactics, and measured in terms of the ranges of performance of individual vehicles. The effectiveness of organizations of vehicles, according to the traditional outlook, has been the sum of the performance of the individual vehicles. The measures of effectiveness that we propose are mission oriented and related to organizational as well as hardware properties. They are the result of attempts to make the vehicle evaluation process more comprehensive and more valid.

Having stated, even in a general sense, the measure of effectiveness for a TLV system, we can immediately see that effectiveness will depend heavily upon the interaction of this system with other systems and with a complex environment. Variations in the mission of the tactical unit, the terrain, and the enemy situation will dictate the appropriate measures of effectiveness of the TLV system (the "tests"); interaction of the TLV system with the above factors will determine the performance of the system (the "scores" on those tests). The effectiveness of TLV organization in a particular mission and environment will depend upon the inherent performance of its vehicles in that environment and also upon the ability of the TLV organization to manage and schedule its human and mechanical resources in order to maintain and effectively utilize its vehicles. The measures of effectiveness proposed, therefore, include parameters which must be derived from both vehicle and organizational characteristics, and alternative TLV systems considered should be permitted to vary in both their vehicular and organizational characteristics. The conceptual evaluation model was planned with these dual goals in mind.

Attention is being given throughout the model-building, and model-articulation efforts to the development of methods that will permit sensitivity or parametric analysis as well as to produce methods of generating response curves and performance envelopes as functions of important system parameters. One important outgrowth of this should be the ability to compare the cost and effectiveness responses to changes in the number of vehicles assigned to an organization, with responses to changes in organizational structure (e.g., more mechanics yielding higher vehicle availability). This should provide military decisionmakers with a wider range of information than is currently available. Finally, an important attribute of the proposed evaluation scheme is that it allows comparisons of dissimilar system alternatives. Thus, wheeled vehicles, tracked vehicles, aerial vehicles, or even pipelines could be compared to one another according to their performance and costs.

Since the measures of effectiveness we propose are mission-oriented, let us look at a simplified version of a typical logistics mission, as shown in Chart 1. A tactical combat unit is moving forward, away from some rear supply point, as a battle proceeds. The tactical logistic vehicle organization must move supplies forward from the supply point to the combat unit, over specified terrain. The amount of work per unit time, which must be done by the tactical logistic vehicle system, increases with time as the diameter of the loop increases. At any time during the mission the total number of vehicles in the TLV organization consists of some which are operating in order to make scheduled deliveries of supplies, some which are "spares" and are not required to meet scheduled deliveries but which can respond to unscheduled demands, and some which are unavailable because they are down for maintenance. As the mission proceeds a point is reached at which there will no longer be any available spares, and at this point the organization's ability to respond to unforeseen demands is seriously reduced. This situation constitutes a serious logistic constraint upon the tactical combat organization. As the battle proceeds further, a point is reached at which the logistic loop is so large that scheduled flows of supplies can no longer be maintained, and the combat organization is further constrained.

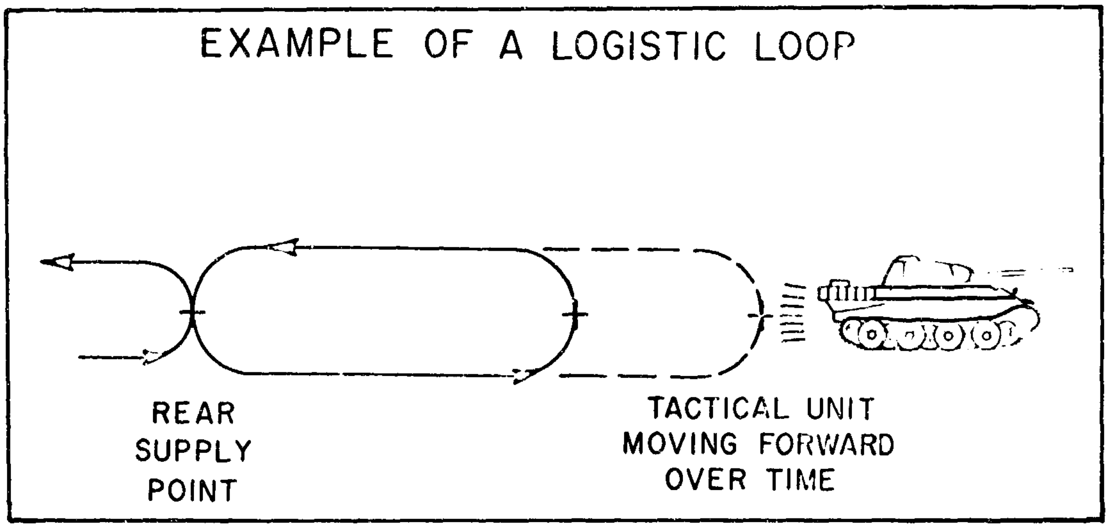

Chart 1

In order to operationalize the concept of "logistic constraints," we can describe the logistic requirements of the combat organizations in terms of a set of parameters and then use estimates of vehicle system performance in order to determine at what points the level of system performance falls below the requirements.

LOGISTIC REQUIREMENT PARAMETERS

1. FLOW RATE
2. RESUPPLY TIME
3. RESPONSE TIME
4. AUTONOMOUS SUPPLY PERIOD

Chart 2

There are four interrelated parameters that may be used to specify the nature of logistics requirements. These are: 1) flow rate, 2) resupply time, 3) response time, and 4) autonomous supply period. Each of these parameters may be measured with respect to a given type of supplies, such as ammunition, POL, or food.

The required *flow rate* for a particular type of supply is the quantity of that supply required by the combat organization per unit of time. Thus, 10 tons per day or 70 tons per week would appear to be equivalent flow rates. However, because of the need for security in combat areas and because of the technological nature of the delivery system, there are significant differences, in reality, between aggregated and disaggregated flow rates. Required *resupply time* is the time period between required shipments to the using combat organization. Thus, if the organization uses 10 tons of ammunition per day, and for security reasons the limit on ammunition stored by the combat organization is also 10 tons, the resupply time required must be 1 day. For simplicity, *we will always refer to the required flow rate as quantity required per resupply time period.* If this choice of time units is for the flow rate, the required resupply time is simply the inverse of the required flow rate.

The required *response time* is the time which may elapse between the issuance of a call or request for a certain item or quantity of supplies and the time by which those supplies must be delivered if they are to be employed most usefully by the combat organization. *The autonomous supply period* is the maximum length of time a combat organization can operate under specified conditions without receiving any deliveries of supplies, if it began the period with its maximum complement of those supplies on hand. Thus, if an armored division begins an operation with a full load of ammunition, its autonomous supply period for ammunition is the period of time until all that ammunition is spent, assuming no intermediate deliveries. The maximum possible resupply time corresponds to the autonomous supply period.

Next, consider a particular TLV system which is to be evaluated. This system consists of a proposed number of vehicles maintenance facilities and manpower; command, control, and communications elements; and vehicle operating crews. We must determine how well a particular TLV system of vehicles, facilities, and men will perform.

The performance of a TLV system will be measured as the flow rate, resupply time, and response time which that system can provide in the particular combat situation of interest. The measures of effectiveness for the system may then be viewed as the degree to which these performance variables meet the required flow rate, resupply time, and response time which were discussed above.

TACTICAL LOGISTIC VEHICLE SYSTEM-PERFORMANCE

1. EXPECTED FLOW RATE
2. EXPECTED RESUPPLY TIME
3. EXPECTED RESPONSE TIME

THESE ARE FUNCTIONS OF

1. CAPABILITY
2. DEPENDABILITY
3. AVAILABILITY

Chart 3

The number of vehicles which must be operating is dependent upon the *capability* of an individual vehicle to perform in the given environment. For each vehicle we must calculate how much it can successfully carry over the terrain of interest and at what average speed. Several Army agencies have developed models that can help to provide this information. In particular, models developed by the Waterways Experiment Station (WES) and the Army Tank and Automotive Command (ATAC) relate ground vehicle performance to terrain conditions and the distribution of obstacles over that terrain.

Another parameter essential to the estimation of the effectiveness of a TLV organization is the *dependability* of its vehicles. Dependability is the probability that a vehicle will complete a mission without experiencing mechanical failures. It is a function of the vehicle construction (inherent dependability), the physical environment in which it operates, and the efficiency of the maintenance organization. Dependability must be estimated from vehicle test data and field experience (TAERS data), or engineering estimates may have to be employed when the vehicles under consideration are only in the design stage of their development. Measures of dependability are useful in the estimation of necessary self-repair capabilities to be built into vehicles and crews, requirements for retrieval equipment, and other factors in addition to availability.

As the vehicles operate over time, some will fail and require maintenance, and some will also require scheduled preventive maintenance. The number of vehicles down will depend, in part, upon the dependability of those operating and the rates of repair for those needing service. In addition, organizational parameters (e.g., repair rates) will affect the *availability* of the vehicle system. Availability may be defined as the proportion of vehicles in operation or operable at a particular time during the mission. Chart 4 illustrates the simple queueing theory model which utilizes failure and repair rates to arrive at an estimate of availability for the organization of vehicles under scrutiny.

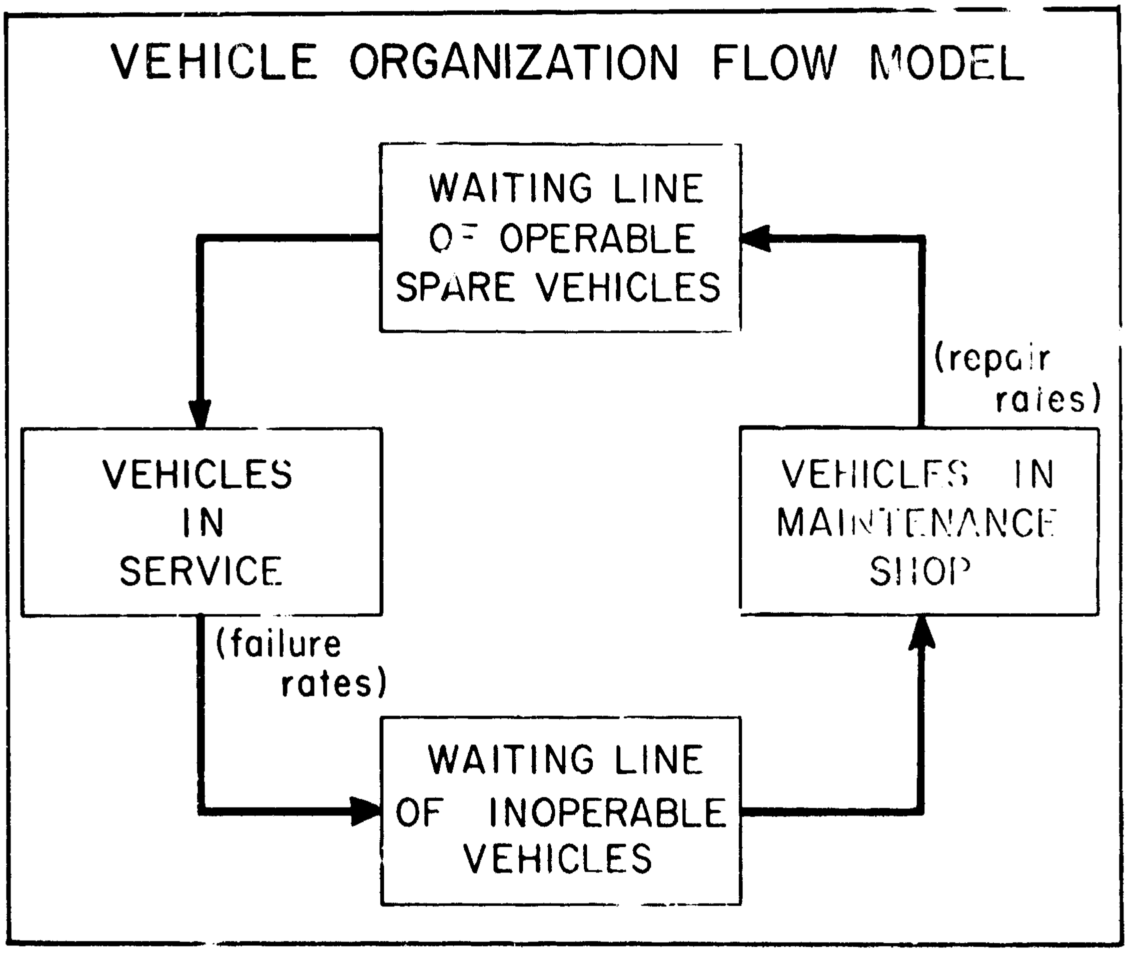

Chart 4

The outputs of models of availability and capability may be combined to estimate expected flow rates, resupply times, and response times as the combat mission continues. The comparison of these parameters with the logistic requirements provides the mechanism by which effectiveness may be measured.

The concepts of effectiveness discussed so far are time-dependent because the models permit the effectiveness measures to change during the duration of the mission. We still require methods which look at effectiveness and costs of systems over much longer spans of time. Ideally, we would like to look at variations in effectiveness over the lifetime of a system as missions and dependability vary. As Chart 5 shows, we need a time dependent view of effectiveness because our system evaluations are mission-oriented, and the spectrum of missions which the system will have to perform must change with time. In addition the wearout and attrition of our current system changes its cost and effectiveness over the years. We have many options as to the time phasing of our RDT&E as well as acquisition of new systems, and decisions between these alternatives should reflect the different streams of effectiveness over time associated with each option. Larry Smith of AMSAA will now present our approach to dealing with this time-dependent view of costs and effectiveness.

REASONS FOR TIME-DEPENDENT

TREATMENT OF COST & EFFECTIVENESS

- SYSTEM EVALUATIONS ARE MISSION-ORIENTED AND SPECTRUM OF MISSIONS CHANGES WITH TIME.
- ATTRITION & WEAROUT CHANGES COST & EFFECTIVENESS OF CURRENT INVENTORY OVER TIME.
- RDT&E AS WELL AS ACQUISITION CAN BE ACCOMPLISHED AT DIFFERENT PACES-EACH WITH AN ASSOCIATED STREAM OF COSTS AND BENEFITS.

Chart 5

VEHICLE EVALUATION

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Captain Wachs has discussed the need for a time-dependent definition of materiel system costs and effectiveness. I shall present our approach toward making these concepts operational.

We can present to the decisionmaker the types of information shown in Chart 1.

Given a target date, n, we want to determine the minimum cost to attain a given level of effectiveness by them.

If we choose a target date, such as the point n on the abscissa of Chart 1, notice that we can reach effectiveness α_1 at a cost which is less than the cost of maintaining the present level α_p. Reaching α_2 by this time will cost us still more. Notice that because of constraints on the problem, α_3 cannot be reached by time n, no matter what we spend. Consider another tradeoff. If we wish to spend $C\alpha_2$ dollars, we can achieve α_2 by time n, or we can reach α_3 if we wait until a later date.

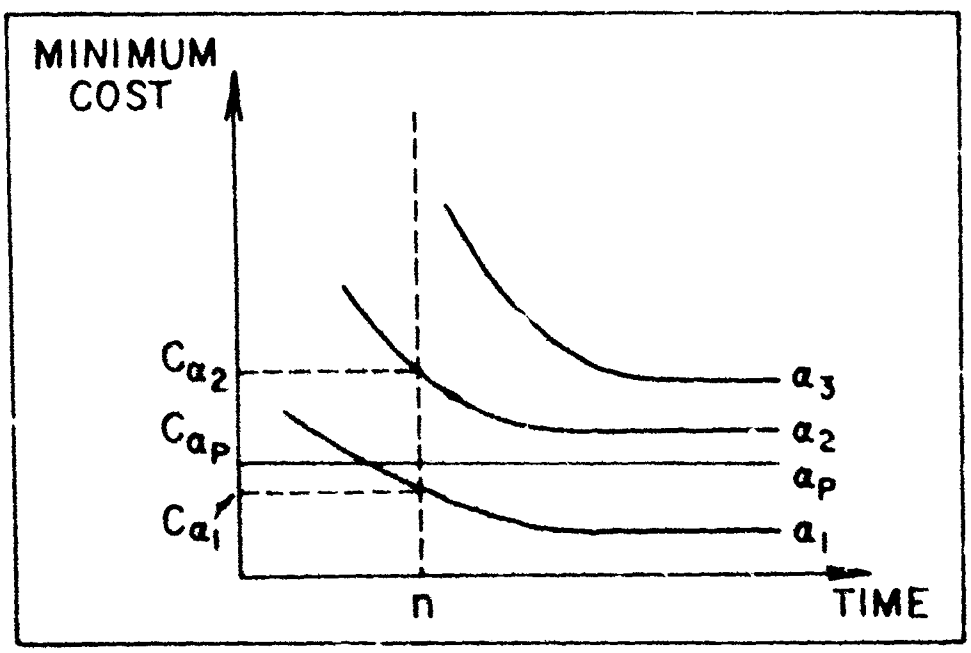

Chart 1

The model that we develop should not only yield the minimum cost overtime to reach a given level of effectiveness, but should also provide a strategy for achieving that minimum; that is, our model should give us a minimum cost allocation of resources.

The general format for obtaining this desired information is shown in Chart 2. This figure is fairly self-explanatory. The general idea is to select the minimum cost allocation for parametrically fixed levels of effectiveness. These levels of effectiveness are reflected as *Return* constraints in the following way: an allocation feasible over the set of return constraints will be at level α_n, by time n and well maintain the minimum levels, α_j, for $j = 1, \ldots, n - 1$.

OBJECTIVE:	Allocate resources so as to minimize the cost of achieving some desired level of effectiveness by the target year. n.		
CONSTAINTS:			
	Return:	1.	Level of effectiveness at time n is $_n$.
		2.	Level of effectiveness up to time n is at least $_j$ (j=1, ..., n - 1).
	Production:	Capacity of Production Facilities.	
	Inventory:	1.	Accounting
		2.	Storage Capacities
	Other:	Organizational Considerations	

Chart 2

I will illustrate these concepts with reference to a specific application on which we are now working.

TACOM is conducting an evaluation of the cost-effectiveness of using radial tires in the tactical vehicle fleet. In support of this study, we are developing minimum cost policies for phasing over from the conventional (bias ply) tires to radials.

The problem description is shown in Chart 3. Given that we wish to have the entire fleet using radial tires by some time in the future, we wish to phase-over in a way that minimizes total system cost. The relevant cost components are listed under *Objective* in Chart 3.

OBJECTIVE: To phase-over tactical vehicle fleet from conventional to radial tires in a way which minimizes the following costs:

- Production
- Shipment from production points to units
- Shipment of usable conventionals from a unit which has converted to one which has not.
- Operating
- Capital

CONSTRAINTS:

Return:	Maintain some minimum level of effectiveness over time horizon.
Production:	The production of a given size radial tire is constrained by the availability of molds
Inventory:	A unit cannot use both radials and conventionals of the same size in a given time period.
	Initial shipment of radials is made in the phase-over period.

Chart 3

The return constraints are set by choosing the time at which the phase-over is to be complete. This selection of the phase-over period sets bounds on the effectiveness. If we assume that the radials are more effective, our system is at least as effective as the wholly conventional system during the phase-in. After the phase-over is accomplished our system effectiveness is that of the wholly radial system.

There are physical production constraints for radials, because of the limited availability of molds for the various tire sizes, but the production of conventionals is taken to be unconstrained.

Organizational considerations generate a special type of inventory constraint in this problem. It is highly undesirable to mix radial and conventional tires on a vehicle, because it degrades the life of both types of tire and can cause vehicular instability. Because of control problems at the usage points, it has been decided that to avert this mixing, and a unit will have only one type of tire in inventory during a given time period. Furthermore, since the conditions for tire storage are much more favorable at the production point, we will not ship radials to the unit before the period in which we decide to have it switch to radials.

We have formulated this problem as a mixed-integer linear program, which we should be able to solve using one of the existing techniques.

Chart 4 represents part of the output of our model. The curve shown can represent the effectiveness level bounded as I previously described. Notice that there is a region ($n^* < n_0$) in which no feasible solution exists, because we are unable to produce enough radial tires to phase-over the whole system. As n^* increases the problem becomes less constrained, and therefore the minimum total cost decreases.

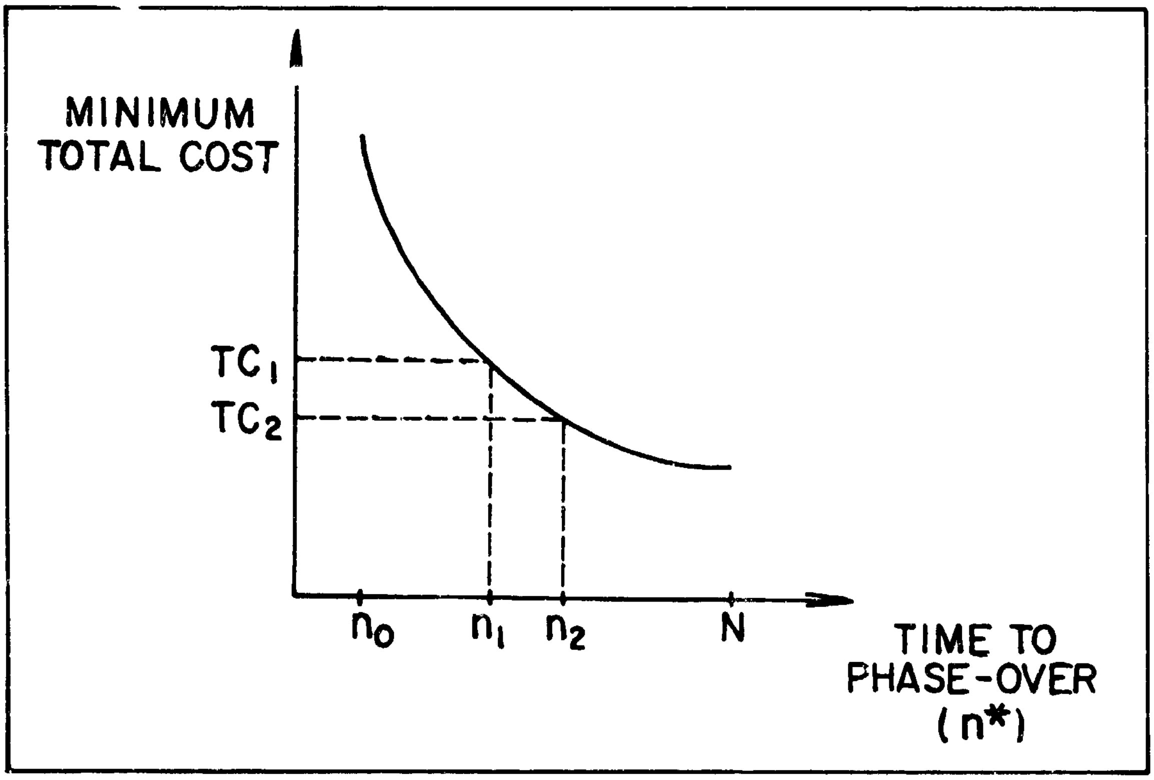

Chart 4

One of the things which the decisionmaker can weigh is the value of obtaining the effectiveness of an all-radial system at time n_1 over that at n_2 versus the difference in cost.

We can define cost curves for other levels of effectiveness by employing different bounding rules. For example, we may be able to isolate certain tactical units where radial tires are particularly effective and give these priority in the allocation of the available production. This is a more restricted problem, and the cost curve would be higher than that shown in Chart 4. The decisionmaker can weigh this increased "effectiveness" against the increased cost. If we are able to define explicit effectiveness relationships, we would be able to use these as the return constraints.

Finally, by relaxing the requirement that the two types of tires cannot be mixed in the unit's inventory system, we can give the decisionmaker an estimate of how much he might be willing to spend for a control system.

In order to treat the problem quantitatively, we need data. Currently, we're optimistic about data availability, as shown in Chart 5. Much of the data should be readily obtainable.

- We have a long history of using conventional tires; hence, costs and usage rates are probably well documented.

- Shipping costs should be readily available.

- We will attempt to estimate demands from such things as the number of vehicles in various organizations, tire life data, and the histories of miles driven by the vehicles in a given organization.

For some inputs, such as the cost of producing radials and the production constraints for them, we will necessarily rely on manufacturers' estimates.

We have attempted to show our approach to defining materiel system cost/effectiveness, and how this thinking manifests itself in the formulation of specific problems.

DATA

- Readily Obtainable

  Cost of Producing Conventionals

  Shipping Costs

  Estimates of Demand

- Manufacturer's Estimates

  Cost of Producing Radials

  Radial Production Constraints

Chart 5

INFORMAL REMARKS TO AMC SYSTEMS ANALYSIS SYMPOSIUM

Honorable Alain C. Enthoven
Assistant Secretary of Defense (Systems Analysis)
Office of the Assistant Secretary of Defense

I'm very pleased and grateful for the chance to speak to Army systems analysts and executives working in systems development and logistics management. First, I think the Army has substantial achievements in these areas of which it can be very proud, and I want you to know that this is my view and my staff's view. Second, I believe in the purposes of your symposium, and I particularly want to emphasize the thought that improved understanding of systems analysis both in and out of the field is very important today From what I read in the newspapers lately, it looks like we're going to have a lot of new explaining to do. Third, I have a great deal of respect for your knowledge and responsibilities, and I expect that the members of my staff attending the symposium and I will personally benefit from exchanging views with you here. In this regard, I hope my part of the meeting can be informal, and I will be happy to answer your questions. Finally, I am honored to have been asked to speak to you; I hope you'll find the result worthwhile.

I propose to discuss briefly the following topics:

- The working principles of systems analysis as it is used in the Office of the Secretary of Defense.

- The present state of materiel systems analysis, mainly, of course, in relation to the Army's weapon system and other materiel needs.

- Some of the relatively new management and analysis tools we are using in the Army materiel area.

- The general DOD budget situation and how it may affect Army materiel programs.

I also want to note that I do not claim expertise in logistics management or new weapons design and development. I've learned a lot about them in the past few years, but what I say today still must necessarily be from a more general standpoint rather than from detailed knowledge.

Systems Analysis in OSD

Systems analysis is used by the Secretary of Defense to ensure that alternative levels and mixes of forces are identified and analyzed before he makes a decision or a recommendation to the president. This use has become a routine matter and I think there is no question but that it is right—the secretary should consider such alternatives. In my opinion, the search for alternatives and their explicit consideration at all decisionmaking levels in the Pentagon are a vital part of the Defense decisionmaking process. Because of the character of the issues involved, as well as the complexity and uncertainties inherent in any defense program decision, it is not enough for the Secretary of Defense to consider a single staff solution, no matter how well-reasoned it may be. Most decisions regarding the size and mix of our forces require broad judgments about the specific objectives that are being sought and the circumstances in which the forces are to be used. These are matters of broad national security policy, and the only way the Secretary of Defense can effectively translate his judgment about them into action is by choosing from among alternative programs. Systems analysis helps to identify and clarify the key issues and assumptions in the alternatives, as well as to present the alternatives in such a way that the Secretary and other politically responsible generalists can understand the essentials and make a reasoned decision.

A second distinctive feature of systems analysis for the Secretary of Defense is an explicit awareness that our overall national resources are limited. Thus, we accept the relevance of cost in defense programs, and, in particular, the total, long-run system cost in all its different components, not just procurement or operating costs in this year's budget. As you know, many people still believe that cost simply isn't relevant to defense—that where national security is concerned money is no object. I agree that we should not let arbitrary financial limits prevent us from buying the military power that we really need to assure our national security, but to go from that premise to the conclusion that money is no object is simply unrealistic. We must consider the cost of our programs in deciding whether or not to pursue them, because resources are limited and cost, therefore, is really effectiveness foregone elsewhere.

The third important characteristic of our systems analysis activity is the way we use the tools of analysis. For example, while our quantitative methods range from the simple to the most complex (although, usually, we're just doing arithmetic), our emphasis is not on the methods themselves but, rather, on defining and solving problems as completely as we can by whatever means are appropriate. Our analyses aren't just quantitative; they also include discussions of nonquantitative aspects of the problem and, as you know, these aspects often have critical significance. Moreover we try to point out the limitations of the quantitative parts of an analysis to put them in the right perspective relative to the overall problem.

A fourth distinctive feature of our systems analysis activity is the concept of open and explicit analysis. By that, I mean that for each major program decision the Secretary of Defense has required that supporting analyses be circulated to all interested parties. In this way, all interested parties can see the methods and assumptions used and how the conclusions were reached. The result is the greatest possible assurance that the Secretary of Defense will hear all sides and have a much better statement of the issues, the assumptions, and the uncertainties than would otherwise be the case.

Fifth, and very important, systems analysis for the Secretary of Defense means understandable analysis. To be perfectly frank I must say that a great deal of almost totally incomprehensible material comes to our top level decisionmakers as rationale meant for their personal consideration. As a result, a great deal of our effort is spent just in explaining such cases so they really can be understood. Obviously, the decisionmaker wants to be free to concentrate on those aspects of the problem where his judgment is needed. He should not have to use judgment to make up for an unclear explanation. This does not mean that the decisionmaker must have explanations of the most minute details, and I don't mean to say that decisionmakers should not have faith in their subordinates. I do mean, however, that whatever information is presented should be something the decisionmaker can really use. The information and logic must be understandable; otherwise, the decisionmaker might just as well not get anything but a request for a rubber stamp approval.

My main reason for reviewing these principles here is simply to reaffirm them and emphasize my belief that they should apply to systems analysis activities in every part of the Defense Department. Systems analysis can serve the new administration well, just as it does the current one, and I fully expect that this will be the case.

Weapon Systems Analysis for the Army

In my opinion, systems analysis problems tend to be more complex for Army weapons than for weapons of the other services. For one thing, most Army weapons perform repeated and varied opera[illegible] over long periods of time rather than for a relatively brief period. As an illustration of extremes, contrast the single shot ICBM with artillery. Second, the ranges of possible use and effects of Army weapons often are very broad. Again consider the artillery example. As you know, there are many kinds of artillery ammunition having widely differing effects. Third, most Army weapons are subject to many different kinds of threats. It may be necessary to consider vulnerability to everything from air attacks to peacetime sabotage. Often both nuclear and non-nuclear war problems must be considered. In short, the analyses of Army weapons have to deal with a great many different kinds of situations and, in addition, there is the very difficult problem of determing the relative significance of different kinds of situations. Finally, it is often necessary to analyze a number of different weapons in combination because of close team relationships which further greatly complicate things.

Thus, the quantitative description of land combat processes, as we all know, is a terribly complicated business. The attempts at detailed descriptions have become most complex and lengthy and, I might add, very expensive in terms of analytical manpower. Yet the situation still is anything but satisfactory. It seems to me that certain points have become very clear:

1. Regardless of their validity, most studies using the complex models and simulations are almost impossible for anyone except their authors to understand and, thus, they often fail to have any impact on the ultimate decision processes.

2. These studies often are seriously out of balance, applying great amounts of detailed treatment to some parts of the problem (sometimes, in my opinon, only because it happens to be possible to do so) whereas other important parts are handled in relatively crude ways or not at all. They violate one of the basic rules of good systems analysis, that is, "it's better to be roughly right than exactly wrong."

3. Most important, despite increased sophistication and detail in these studies, they often seem to be pretty illogical. Thus, even through systems analysis work on land forces materiel has increased in recent years, it still seems to be concentrated in a few not very successful major efforts covering a small number of the total amount of weapons and materiel items needing treatment.

At this point, you have every right to demand some kind of positive recommendation, so let me offer the following: we should shift some of our effort away from concentration on minute detail and modeling of complex processes, and we should greatly increase our emphasis on the logical design of analyses and on devising simple, understandable comparisons of measurable capabilities. I think this will improve the quality of our work; and the decisionmakers will be better able to use it because they will understand it better.

We all recognize that decisionmakers usually add many judgments to the numerical facts and logic that they consider. This, of course, is as it should be. My experience is, however, that in most cases where the decisionmaker doesn't personally understand at least the basic structure of the quantitative analysis given to him, he not only adds judgments to the analysis, but he also is more than willing to completely replace the analysis with opinions. I think you probably will agree that a large amount of analytical effort has turned out to be fruitless this way.

Second, I believe one of the best tests of the logic of an analysis is a simple description of the essential features of this logic in layman's language. I will admit that, in principle there can be valid analyses of any degree of complexity, going far beyond even the most intelligent person's ability to comprehend readily. In my experience in defense analysis, we have not yet encountered a real life situation where such complexity was truly necessary. In short, I believe that, if someone's rationale can't be explained in a comparatively simple fashion, it almost always means there's something wrong with it.

We are really very fortunate that this is so because it gives us opportunities to test the soundness of an analytical approach before extensive fact gathering and detailed calculation. This is part of designing systems analyses from the top down, an extension of what I like to call McNamara's First Law of Analysis: "Always start by looking at the grand totals." Whatever problem you are studying, back off and look at the total context in which the problem exists. Don't start with a small piece and work up look at the total first and then work down to the problem. Thus, if you are looking at a matter of cost, look at total system cost, not just this year's procurement but total cost over the useful life of the system.

As applied to designing a systems analysis study, the "First Law" calls for defining the problem and looking for the ultimate logic that should be used to decide the issue in question. This sounds obvious, but I'm convinced it has to be said because so many study efforts still seem to charge off on detail without having a logical way of relating det. to the overall problem.

In my opinion, the design phase usually is by far the toughest and most critical part of the whole study. It may require a lot of preliminary cost and effectiveness estimating and rough trials, and it may take up a significant portion of the total time spent on the study. It also often takes an iron will to carry out, because for a while there may not be much to show on the matter. The bosses may be demanding to see a sizeable team of analysts busily generating books full of information while you are able to show only one or a few study designers still trying to define the problem. We'll just have to keep trying to convince our superiors that there's no point in launching a larger effort until we really know what's needed and how all the parts fit together.

I believe that this kind of redirection to simplicity and understandability will ultimately bring us a greater number of more useful studies.

Because we were having so little success with the large, complex studies, we redirected some of our own land forces analysis along new lines. We began devising Capability Indices for the land forces, which brings me to my next topic.

New Management and Analytical Tools

We have spent about a year now on the Capability Indices. Many are based on materiel capabilities. For example, we calculate quantities such as the total lethal area per minute that our artillery forces are capable of "producing," and the total troop miles per month that our lift helicopter forces can carry.

We are emphasizing straightforward arithmetic calculation in these measures, nothing fancy. We are reasonably sure that everyone who may use them in the decisionmaking process will understand them. And while I admit that they're rather primitive, I do believe they will have great utility. I expect the main uses will be in force comparisons for setting overall force levels and for evaluting force mix alternatives. We already have set overall force levels in a very elementary way, in a comparative appraisal of NATO and Warsaw Pact force levels. This comparison has turned out to be one of the most useful devices we have for analyzing the situation in Europe.

We do not yet have a force mix comparison based on the capability indices. However, what we have in mind are equal cost and equal effectiveness trades. It should be possible with the indices to get a reasonable idea of how a new materiel item would affect overall force capability when replacing something of the same general type that we already have, or plan to have. Thus, we can see whether, and how much, overall force capability would be increased by putting in a given quantity of a new item and taking out an equal dollar amount of some other item or items (an "equal cost trade"). In addition, we can see whether and how much total force costs vould be reduced by putting in only enough of a new item to replace the *effectiveness* of the items dropped out (an "equal effectiveness trade"). Needless to say, if the new item is more efficient than the old, a substitution between the equal cost and equal effectiveness amounts would provide both increased force effectiveness and reduced force cost.

In my opinion, if the services increase their use of this kind of tradeoff analysis, they will improve the quality of their efforts on evaluating new items. This, in turn, should certainly lead to better service proposals for force changes and, ultimately, to more effective forces. It would be a vast improvement over today's situation where most proposals are either for a pure add-on or for a one-for-one replacement with a more expensive, and hopefully more capable, item. Collectively, such proposals amount to little more than a shopping list for the total of which there is never enough money. This simply means that the services fail to contribute all they should to helping the Secretary of Defense choose.

The AH-56 procurement decision earlier this year was made on an equal cost trade basis. As you know, the AH-56 is a heavily armed helicopter which promises a major advance in our capability to provide responsive, discriminate fire support near our ground troops. It also appears interesting as an antitank weapon.

Early this year, the Secretary of Defense approved a plan recommended jointly by the Army and OSD which will phase in AH-56s while trading off existing items and personnel which would cost the same over 10 years. If we are right in going ahead with this procurement, it should be the case that the tradeoff of tube artillery, tanks, and less capable armed helicopters is appropriate in view of the missions, which the AH-56 is expected to perform. In other words, the new force ought to be more effective than the one it replaces. Perhaps the AH-56 superiority will turn out to be so great that even greater reductions can be taken in other parts of the force structure to achieve some cost savings. But we do not yet know this. Thus, under the circumstances, the Secretary believed that for now we should plan only on trading for equal cost.

In certain future cases, equal effectiveness trades and improved effectiveness, but reduced cost trades undoubtedly will be appropriate. This in no way implies, however, that there is to be a "ceiling" on the cost or capability of the Army. I understand that questions have been raised along this line. I can only answer that being able to make tradeoff analyses is not the same thing as deciding how to use them. Clearly, whether or not to change a force level is a specific policy decision completely independent of analytical techniques for comparing one kind of weapon or force with another. I expect that our force levels will continue to be set on the basis of our needs as in the past.

Another important addition to our management tools is the Development Concept Paper (DCP). The Department of Defense spends a substantial portion of its budget each year on research and development, and this is clearly one of the most important defense programs. We know that it isn't possible to plan inventions, and that advances in technology are not susceptible to orderly prediction. But when it comes to engineering development programs intended to serve specific military purposes, and having costs measured in hundreds of millions of dollars, we believe Defense Department top management must see to it that the foundations of each program are thought through before we begin to make large financial outlays. We need to have a clear statement of what each program is intended to accomplish, at what cost, in what time, and the reasons why it was chosen in preference to alternatives. The DCP is an attempt to provide this.

The DCP has several purposes. First, and probably most important, it documents the performance, cost, and schedule estimates, as well as the technical risks, which were the basis for the decision to start or continue a development program. We want to establish clearly for the record why a development program was started, what we hope to get out of it, and the key assumptions underlying the decision.

The DCPs do not represent an attempt to insist on precise analysis and completely accurate cost and schedule estimates. This is impossible in an area where large uncertainties are inherent. Nor do we intend to avoid taking chances. Rather, we want to make clear from the outset, the expectations and judgments concerning the uncertainties, risks, and potential payoffs, and to document any disagreements about these expectations.

The goal is to minimize tendencies to over-state expected performance or benefits and under-state costs and risks merely to get a project under way.

A second purpose of the DCPs is to provide thresholds in these estimates which, if exceeded, would call for a reconsideration of the project by the Secretary of Defense. Estimates in a DCP will be periodically updated, and the new estimates compared with the original estimates, so that the Secretary can see if expectations are being realized and if the reasons for continuing the project are still valid. It is in meeting this purpose that the DCP serves as an important management control device and not merely a historical record.

A third purpose, which all DOD management tools have in common, is to provide a means whereby the secretary's staff and the services can communicate with one another on projects of mutual interest. If there are conflicting ideas about the potential usefulness of a proposed new weapon system, these disagreements are brought out into the open and discussed before a great deal of time and money have been spent and perhaps wasted. If there are alternative ways of meeting a projected need, these can also be discussed and compared and a rational allocation of development funds agreed upon.

As you may know, DCPs as a regular procedure are less than a year old. But the best ones show clearly that this technique has a great deal of promise, including, I think, potential for management purposes solely within the Services as well as within the overall DOD framework.

DOD/Army Budgetary Situation

We face major financial problems for FY70. We're going into the final stages of budget preparation with a budget submittal from the services, which is considerably higher than the FY69 program. There are strong competing demands for every dollar we want to spend. And this isn't just a short run phenomenon, a part of this year's budget "crunch." It's a problem that's going to be with us permanently.

Yet, I seriously doubt that there is enough practical reflection of this in the Army materiel field. We keep developing major items of equipment that will be much more costly to procure and operate than their predecessors. There would be nothing wrong with this if we could be confident that the increase in effectiveness was at least in the same proportion as the increase in cost. We are buying systems where this clearly is the case: for example, the C-5A and Poseidon. But for a significant number of systems, we are at best uncertain. Because of the complexity of land combat, we may usually be uncertain whether the new system is more effective in relation to cost than the old one. I wouldn't want to argue that we should never go ahead with a new one unless we can prove conclusively that it is more effective. But we shouldn't go ahead, on the other hand, just because it is new and there is no conclusive proof that it is less effective in relation to cost. A judgment will always be needed. And we should be clear on the point we're judging. That is, is the new system more effective than the old in relation to total system cost?

It's important that we make the right judgment, because the more costly the weapons, the fewer there are. A mistake in a judgment of this kind could mean a drop in our total effectiveness. I know you realize this, but I feel the point needs to be stressed anyway since we still seem so far from a really satisfactory solution to the problem of increasing cost and complexity of weapon systems.

COST ANALYSIS TECHNICAL MANUAL (CATEM)

Lt. Barry E. Feldman
Systems and Cost Analysis Division
Comptroller/Director of Programs
HQ. U.S. Army Materiel Command

Purpose of Briefing

The purpose of this portion of today's symposium is to present to you a discussion of the major effort being undertaken by the Systems and Cost Analysis Division to develop a technical reference capability, which will put the variety of available analytic techniques in their proper perspective with regard to the performance of the myriad of AMC functions and provide AMC personnel with the tools necessary to perform their functions with a greater degree of precision and sophistication.

Content of Manual

This effort, entitled the Cost Analysis Technical Manual (CATEM), is designed to present chapters that deal with specific theories, concepts, and models from four basic disciplines, as related to the total spectrum of cost analysis activities. (Chart 1) These disciplines are: Cost Analysis, Economics, Operations Research, and Statistics. Each chapter is designed to present a theoretical discussion, followed by demonstrative cases and applications to cost analysis and related AMC activities. The following charts contain the titles of the 12 chapters under preparation. (Charts 2 and 3).

COST ANALYSIS TECHNICAL MANUAL (CATEM)

- DISCIPLINES COVERED -

1. COST ANALYSIS
   a. COST CONCEPTS
   b. MATHEMATICS OF FINANCE
   c. DATA COLLECTION
2. ECONOMICS
3. OPERATIONS RESEARCH
4. STATISTICS

Chart 1

COST ANALYSIS TECHNICAL MANUAL (CATEM)

- CHAPTERS -

1. INTRODUCTION
2. COST CONCEPTS
3. PRINCIPLES OF STATISTICS AND THEIR APPLICATION TO AMC ACTIVITIES
4. THE APPLICATION OF THE TIME VALUE OF MONEY THEORY TO AMC COST EVALUATION ACTIVITIES
5. THE TOTAL INFORMATION SYSTEM IN AMC SYSTEM DECISION-MAKING
6. THE APPLICATION OF OPERATIONS RESEARCH TECHNIQUES TO AMC ACTIVITIES
7. THE THEORY OF IMPROVEMENT CURVES

Chart 2

COST ANALYSIS TECHNICAL MANUAL (CATEM)

- CHAPTERS -

CONT'D

8. FORECASTING OF COSTS (COST ESTIMATING RELATIONSHIPS)
9. A MODEL TO TEST THE ACCURACY OF ARMY MATERIEL PLAN ESTIMATED PROGRAM UNIT COSTS
10. A MODEL TO ESTABLISH THE REASONABLENESS OF ARMY MATERIEL PLAN ESTIMATED PROGRAM UNIT COSTS
11. A MODEL TO ISOLATE THE CAUSES OF UNIT COST CHANGE THROUGH TIME
12. A MODEL TO DEVELOP AN EARLY WARNING SYSTEM OF SUBSTANTIAL CHANGES IN THE TOTAL COST OF A SPECIFIC PROGRAM

Chart 3

Objective

As is evident from the titles of the first eight chapters, our original objective was to prepare a complete manual of the known theory and available techniques necessary to perform the various tasks of systems and cost analysis, as well as other related activities. As the work initially progressed, it became increasingly obvious that this manual was particularly needed to provide four important capabilities

- The means to determine the accuracy of cost estimates;
- The means to establish the reasonableness or the quality of cost estimates;
- The means to more precisely forecast unit costs for an ongoing program; and
- The means to know as early as possible if a unit cost is escalating more than should be expected.

Therefore in addition to writing a manual to serve as a basis for future model building, a priority effort was required to develop new cost estimating and cost analysis techniques. Chapters 9 through 12 represent just such a means to that end.

Chapter 9

In Chapter 9, a methodology is presented to examine the accuracy of current cost estimating practices. Since there have been six Army Materiel Plans (AMP) issued, a data bank was readily available for testing. To illustrate the methodology employed, the actual and estimated Program Unit Costs (PUCs), as set forth in the AMP reports for the years 1962 to 1967, are extracted and arranged in the following matrix. (Chart 4)

The rows r_1 to r_6 represent the AMP reports 1962 to 1967. The columns t_1 to t_8 are the fiscal year buys, as reported in each of the AMPs. The fiscal year t_1 corresponds to the year of an actual unit cost, t_2 represents the year of the estimated current AMP year unit cost, and the other fiscal years represent the successive annual unit costs. For example, cell P_{12} represents the estimated procurement cost for the year 1962, as reported in the 1962 AMP; cell P_{21} is the actual procurement cost for the year 1962, as reported in 1963. Now, what we have done is to divide an estimated unit cost, for example, cell P_{12} by the corresponding actual unit cost, in this case, cell P_{21}. We can state that the estimate is x percent of the actual unit cost. By examining these available one year forecasts (Chart 5), two year forecasts (Chart 6), three year forecasts (Chart 7), and four year forecasts (Chart 8) a mean accuracy for each forecast period can be determined.

COST ANALYSIS TECHNICAL MANUAL (CA:EM)

AMP YEAR \ FY	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8
r_1	P_{11}	P_{12}	P_{13}	P_{14}	P_{15}	P_{16}	P_{17}	P_{18}
r_2	P_{21}	P_{22}	P_{23}	P_{24}	P_{25}	P_{26}	P_{27}	P_{28}
r_3	P_{31}	P_{32}	P_{33}	P_{34}	P_{35}	P_{36}	P_{37}	P_{38}
r_4	P_{41}	P_{42}	P_{43}	P_{44}	P_{45}	P_{46}	P_{47}	P_{48}
r_5	P_{51}	P_{52}	P_{53}	P_{54}	P_{55}	P_{56}	P_{57}	P_{58}
r_6	P_{61}	P_{62}	P_{63}	P_{64}	P_{65}	P_{66}	P_{67}	P_{68}

Chart 4

COST ANALYSIS TECHNICAL MANUAL (CATEM)

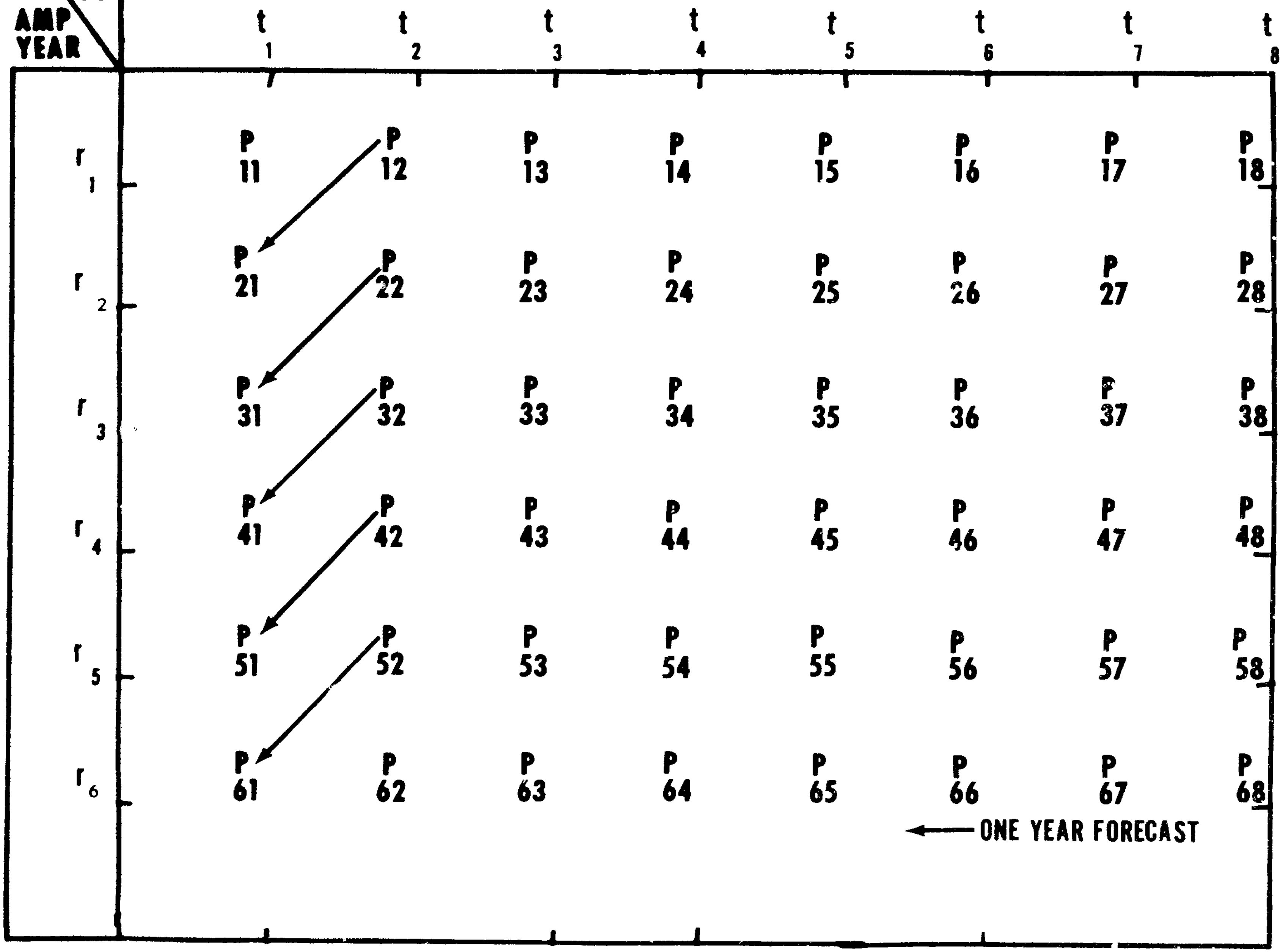

Chart 5

COST ANALYSIS TECHNICAL MANUAL (CATEM)

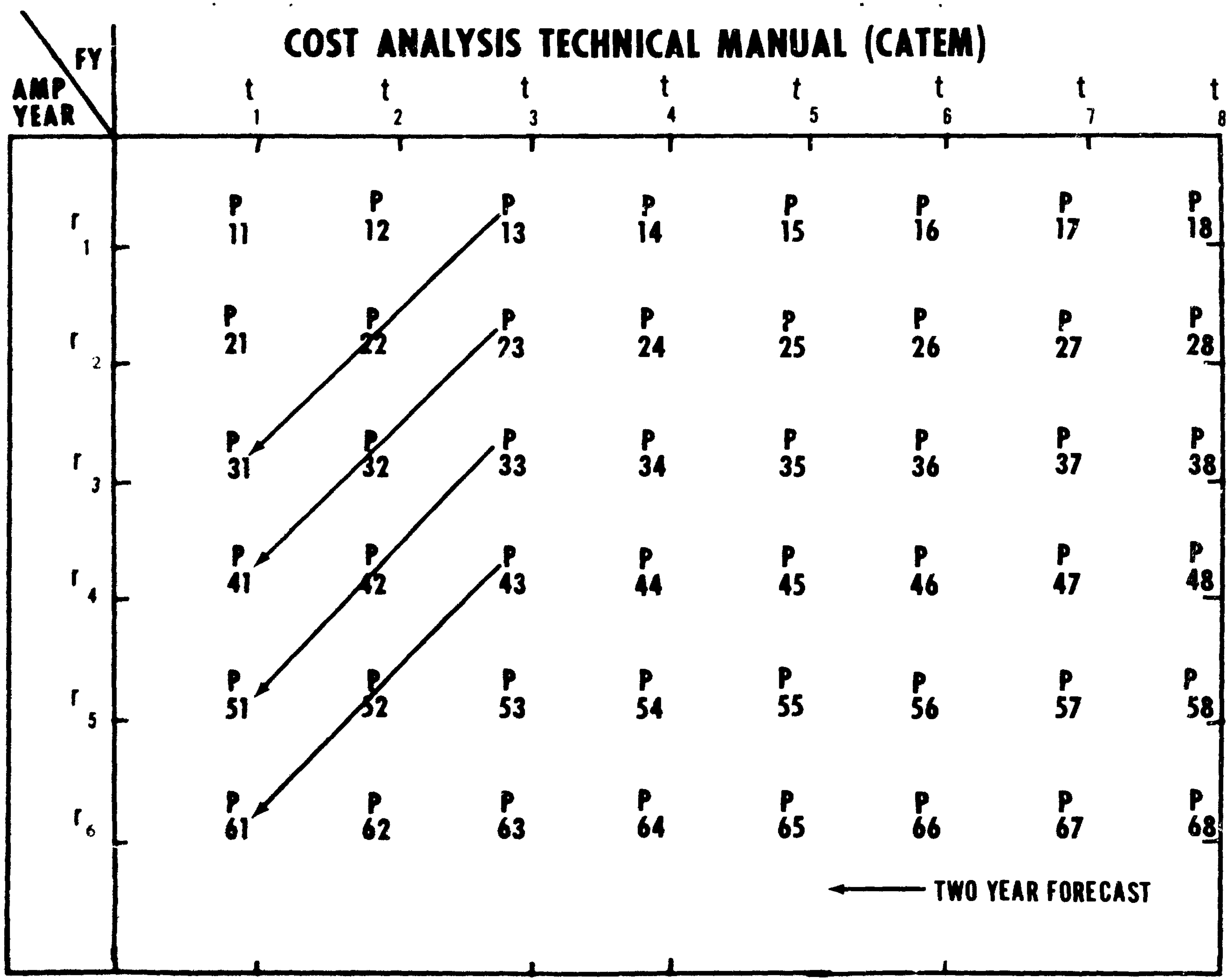

Chart 6

COST ANALYSIS TECHNICAL MANUAL (CATEM)

AMP YEAR \ FY	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8
r_1	P_{11}	P_{12}	P_{13}	P_{14}	P_{15}	P_{16}	P_{17}	P_{18}
r_2	P_{21}	P_{22}	P_{23}	P_{24}	P_{25}	P_{26}	P_{27}	P_{28}
r_3	P_{31}	P_{32}	P_{33}	P_{34}	P_{35}	P_{36}	P_{37}	P_{38}
r_4	P_{41}	P_{42}	P_{43}	P_{44}	P_{45}	P_{46}	P_{47}	P_{48}
r_5	P_{51}	P_{52}	P_{53}	P_{54}	P_{55}	P_{56}	P_{57}	P_{58}
r_6	P_{61}	P_{62}	P_{63}	P_{64}	P_{65}	P_{66}	P_{67}	P_{68}

← THREE YEAR FORECAST

Chart 7

COST ANALYSIS TECHNICAL MANUAL (CATEM)

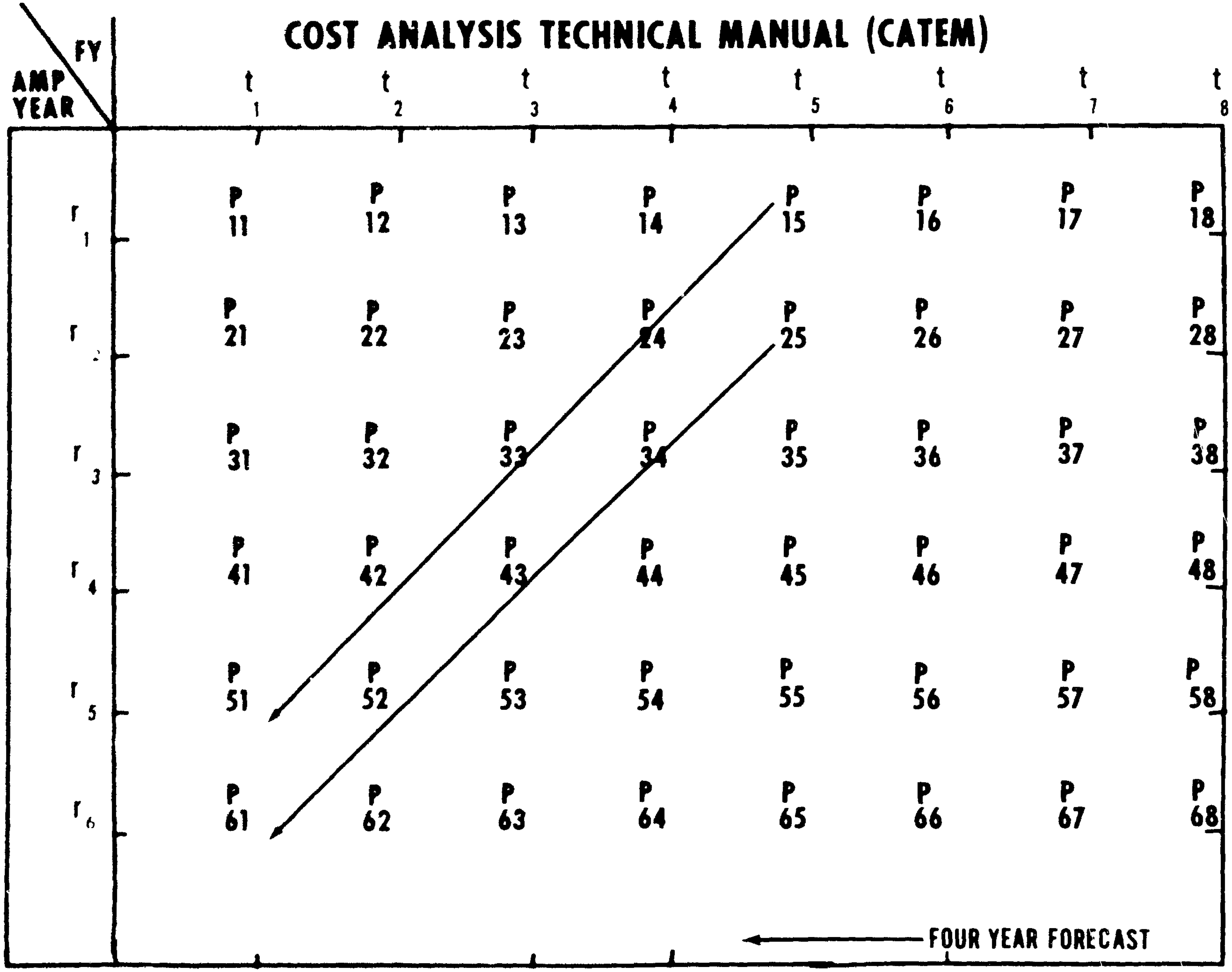

Chart 8

Chapter 11

In Chapter 11, a model is proposed to isolate the several effects upon hardware unit costs over time. (Chart 9) In general notation, the average unit cost, in some future time period r, for the jth item, can be expressed as a function of the following variables: the cost of the first unit produced (P_{0j}); price level changes (I_{j},); engineering change orders (E_{rj}); the learning process (L_{rj}); the annual acquisition rate (Y_{rj}); and an undefined term (U_{rj}), which is largely unexplainable because of the many random events that can occur during the procurement cycle.

COST ANALYSIS TECHNICAL MANUAL (CATEM)

$$P_{rj} = f(P_{0j}\ I_{r},\ E_{rj}\ L_{rj}\ Y_{rj}\ U_{rj})$$

A FUTURE UNIT COST (P_{rj}) IS A FUNCTION OF THE COST OF THE FIRST UNIT PRODUCED (P_{0j}), PRICE LEVEL CHANGES (I_{r}), ENGINEERING MODIFICATIONS (E_{rj}), THE LEARNING PROCESS (L_{rj}), THE ANNUAL ACQUISITION RATE (Y_{rj}), AND AN UNEXPLAINED TERM (U_{rj}), WHICH IS LARGELY UNEXPLAINABLE DUE TO THE MYRIAD OF EVENTS THAT CAN OCCUR DURING THE PROCUREMENT CYCLE.

r = THE PROCUREMENT YEAR

j = A SPECIFIC ITEM WITHIN A COMMODITY CLASS

Chart 9

Chapter 10

Given that this methodology or other techniques are utilized, we next address the question, "Have the prescribed procedures been uniformly applied?" This is Chapter 10 of CATEM. (Chart 10) The answer is provided by determining if an AMP exhibits a normal correspondence between historical and estimated PUCs over the reported fiscal years. That is, by comparing the relationship between each pair of FYs + 1 and FY unit costs, an expected mean and variance can be developed. Before the issuance of an AMP report, each relative unit cost can be compared against an interval of likely outcomes. Those relative unit costs which "fall outside" this interval can be investigated and examined for reliability by each command.

Chapter 12

Unit costs may be typical in relationship to each other. Any one or all of the individual unit costs may, however, be substantially greater than when reported in a previous AMP. In other words, it is necessary to know if there has been an unusual escalation (or deescalation) in unit costs for any future year. This is the purpose of Chapter 12. (Chart 11) Previously, in Chapter 9, we examined the mean relationship between estimates of unit costs (column 2) and actual unit costs (column 1).

COST ANALYSIS TECHNICAL MANUAL (CATEM)

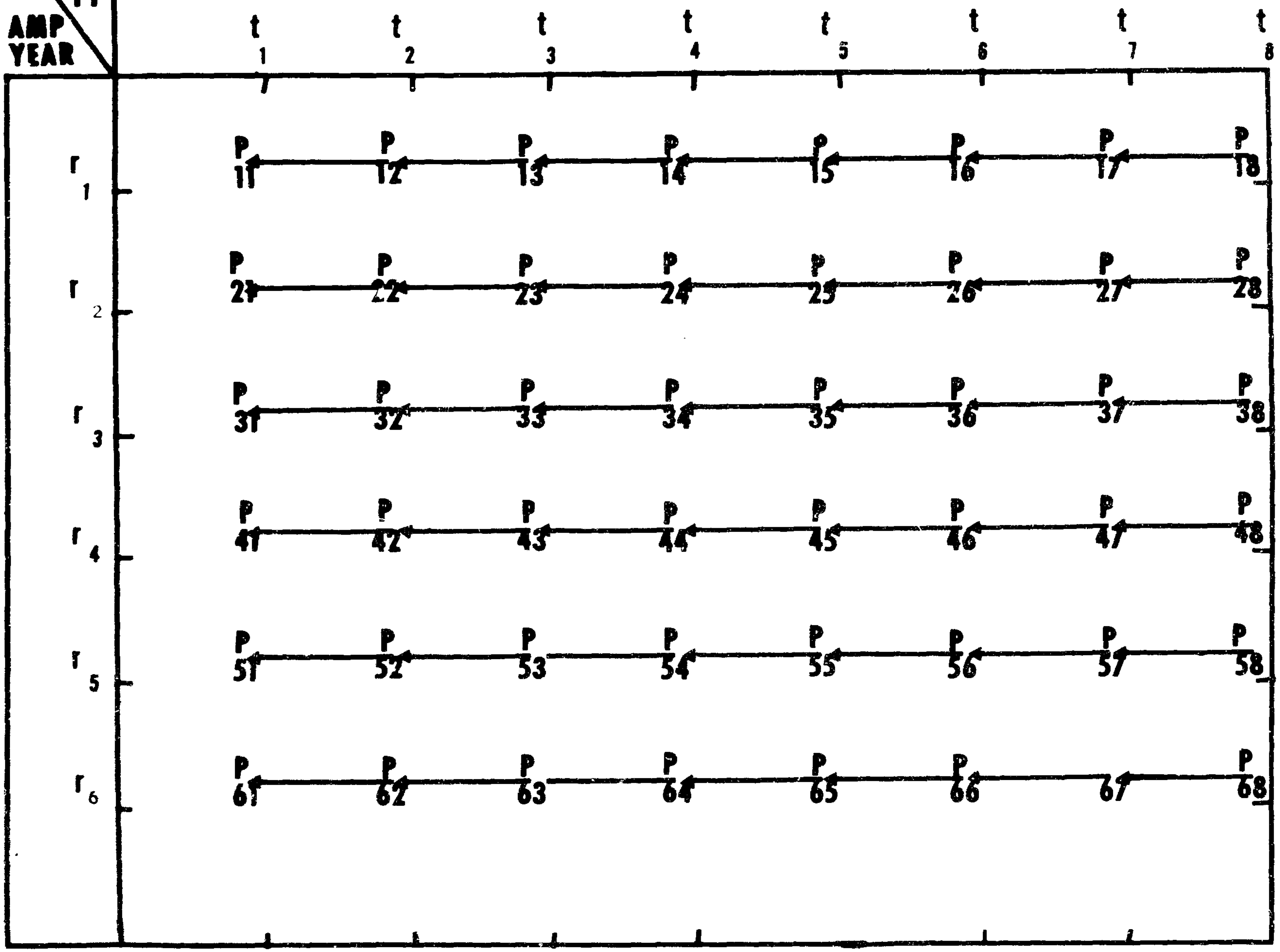

Chart 10

COST ANALYSIS TECHNICAL MANUAL (CATEM)

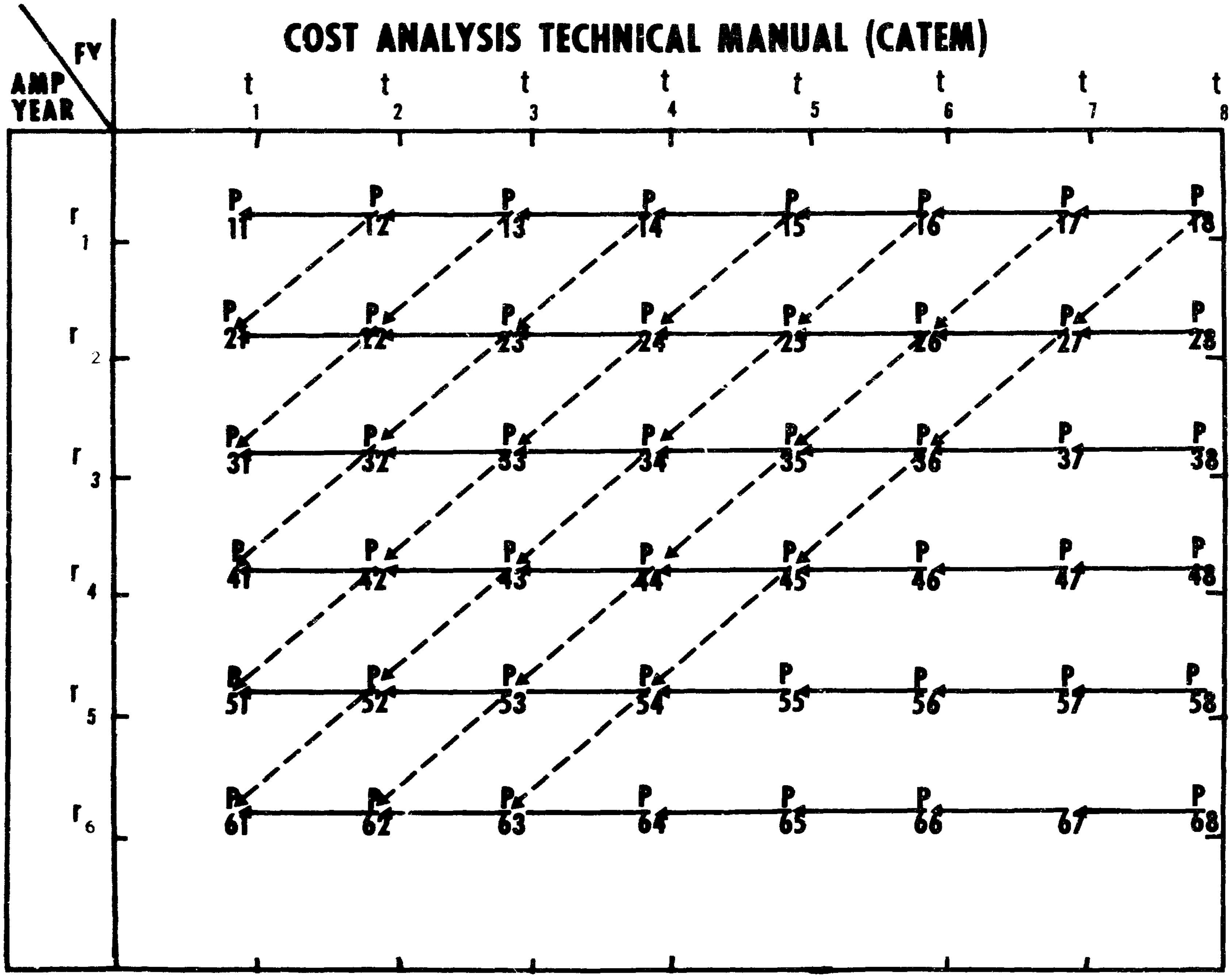

Chart 11

In Chapter 10, we examined the mean relationship between items on the same row. Now, still using the same data, we examine the relationship over all periods of time. (Chart 12) Actually what we are doing is to apply the basic concept of the distinction between shifts along a curve versus shifts of a curve.

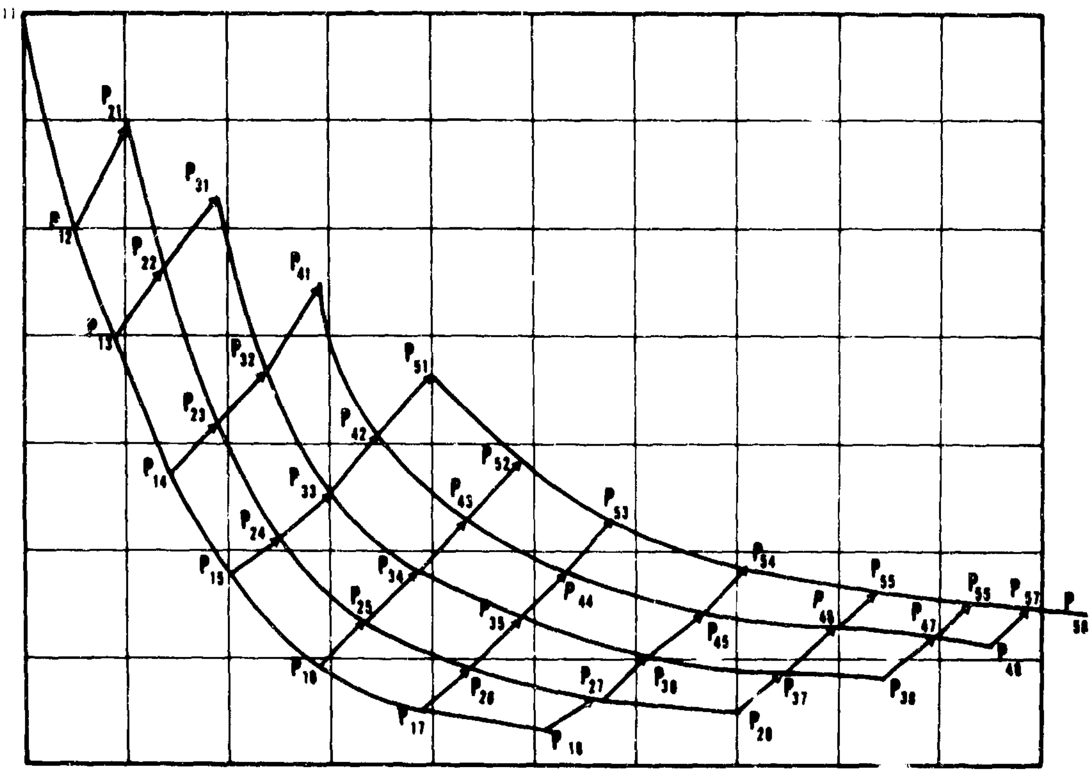

Chart 12

Conclusion

The preceding has been a brief summary of the models developed in Chapters 9 through 12. Copies of these chapters and the results will be furnished by mail upon request. These models were conceived by and tested under the direction of Dr. Donald T. Barsky, who is presently consultant to the Systems and Cost Analysis Division, Comptroller and Director of Programs.

A NEW GRAPHIC PROBABILISTIC APPROACH TO PERT

Dr. Donald T. Barsky
Consultant to the Systems and Cost Analysis Division,
Comptroller/Director of Programs,
HQ, U.S. Army Materiel Command

One of the management science techniques available to the cost estimator is PERT or PERT/cost. As you are aware, although this technique has substantially advanced management's capability to plan and monitor large-scale projects, too often the original project time or cost estimates have been substantially in error.

In CATEM a new graphic probabilistic approach to PERT is developed. The methodology described suggests that a large part of the estimating error is not caused by the inability to more accurately forecast the future, but by the failure to completely present the likely outcomes of a project. A simple example serves to effectively explain this hypothesis. (Chart 1).

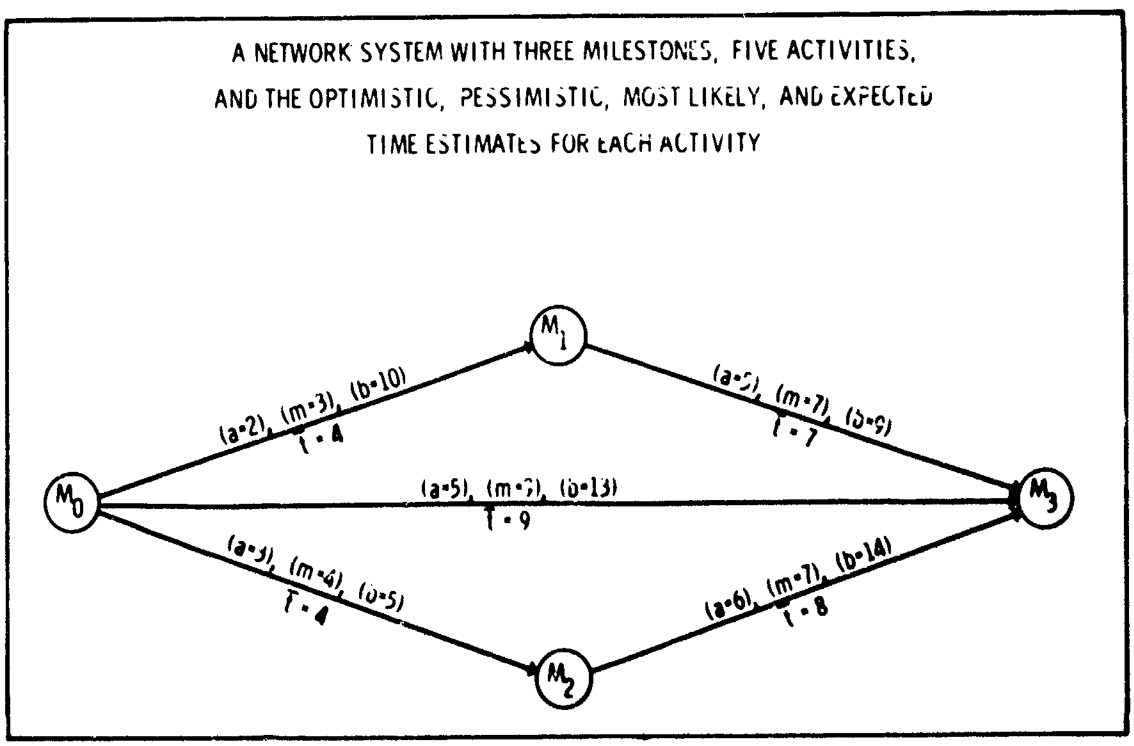

Chart 1

Assume that a project consists of three milestones, five activities, and three independent paths. Note, consistent with present practices, there are three outcomes specified for each activity. That is, the "a", "b", and "m" values are, respectively, the optimistic, pessimistic, most likely outcomes. Further, as these values are theorized to be the endpoints and the mode of a beta distribution, the probabilities of each outcome are 1/6 for each of the endpoints and 4/6 for the mode. Beneath each activity arrow is the mean outcome $\bar{t}$, calculated from the a, m, and b values. Comparison of the mean time for each path reveals the critical path with a mean time of 4 + 8, or 12 time periods.

Of course, this value and those to be alternatively developed are not the solutions of deterministic models. In a formal sense, considerable uncertainty exists, as the probability distributions of activity outcomes are not known. Therefore, analyses in terms of expected values and variances are not on firm ground. Equally important, however, is that the probability measures are a description of the state of belief of the person who makes the probability estimate and that this measure is being used to cause the decision to be consistent with these beliefs.

The important point to be made now is that each of the other two paths could also become the critical path. If only the pessimistic outcomes occur, the project will consume 10 + 9, or 19 time periods. It becomes apparent, then, that the mean expected time for the entire project must be derived from all the activity outcomes and not just the anticipated critical path. Equally important is that the mean may not be very representative of the eventual program outcome. Therefore, it is also necessary to know the variation about the mean.

The first step in the model is to assign an outcome code to each activity time (Chart 2). For example, the outcome of Activity A_1 could be 2. This result is arbitrarily assigned a letter code, a. Similarly, each of the other outcomes is coded b through o.

A HYPOTHETICAL NETWORK SYSTEM WITH CODED OPTIMISTIC, MOST LIKELY, AND PESSIMISTIC TIME ESTIMATES FOR EACH ACTIVITY

ACTIVITY A_i	OPTIMISTIC ACTIVITY-TIME A_{it_a}	MOST LIKELY ACTIVITY-TIME A_{it_m}	PESSIMISTIC ACTIVITY-TIME A_{it_b}	OUTCOME CODE
A_1	2			a
		3		b
			10	c
A_2	5			d
		7		e
			9	f
A_3	5			g
		9		h
			13	i
A_4	3			j
		4		k
			5	l
A_5	6			m
		7		n
			14	o

Chart 2

Next, all the combinations of activity-time outcomes are listed, using the previously assigned codes. The complete listing for this example consists of 3^5 or 243 different combinations. Only a few are cited here (Chart 3). Thus, combination C consists of outcomes a, d, g, j, and m. By just changing the last outcome from m to n, a second combination is formed. Notice also that, hereafter, a path is redefined as a sequence.

A SAMPLE OF THE POSSIBLE COMBINATIONS OF ACTIVITY-TIME OUTCOMES
FOR A HYPOTHETICAL NETWORK

Combination C_j	Sequence S_1	Sequence S_2	Sequence S_3
1	a & d	g	j & m
2	a & d	g	j & n
3	a & d	g	j & o
4	a & d	g	k & m
.			
19	a & d	i	j & m
.			
243	c & f	i	l & o

Chart 3

Using an entirely different format, (Chart 4) each of the possible combinations is depicted as a spoke of a wheel. The concentric bands represent the paths within the network. For a better understanding of this chart, think of each path being completed before beginning another one. For example, at the origin, milestone M_0, one of three outcomes can occur. If an outcome equal to 3 time periods occurs, then we proceed along this line to milestone M_1. Next, if an outcome equal to 7 occurs, we arrive at milestone M_3. The progress along this path also takes us from milestone M_0 to M_3. Assume an outcome of 9, and we continue toward the circumference. Finally, along the last path, if outcomes 3 and 6 occur, we arrive at a terminal point which is one of 243 such possible points.

A Hypothetical *PERT* Network With 243 Combinations

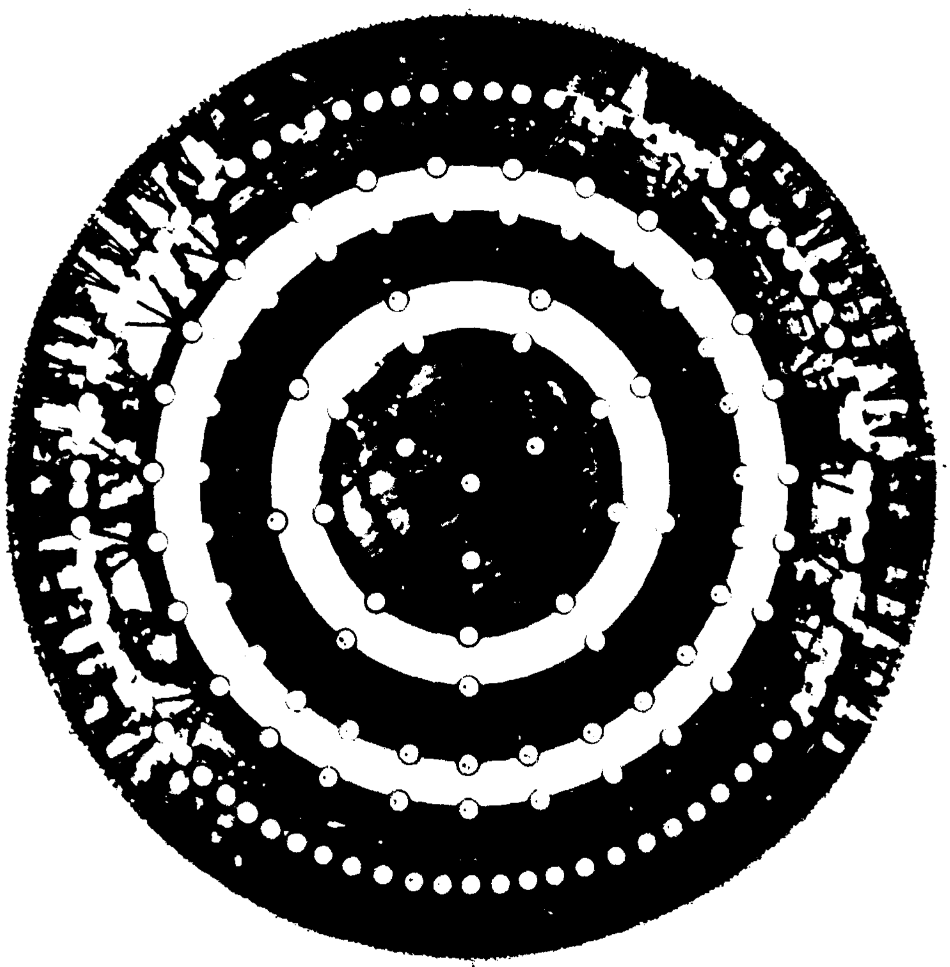

Chart 4

Returning to Chart 3 we next substitute the t periods of time specified for each of the coded outcomes. (Chart 5) Within a combination of activity outcomes, that sequence with the largest estimated time becomes the critical path and is denoted by an asterisk. Notice again that sequence 3, defined earlier as the critical path, becomes a path with slack when combination 19 occurs. In that instance, sequence 2 is the critical path.

A SAMPLE OF THE CRITICAL PATHS FOR
EACH COMBINATION OF OUTCOMES

Combination Number C_j	Sequence S_{1t}	Sequence S_{2t}	Sequence S_{3t}	Critical Path Time (t) S_{ct}
1	2 + 5	5	3 + 6*	9
2	2 + 5	5	3 + 7*	10
3	2 + 5	5	3 + 14*	17
4	2 + 5	5	4 + 6*	10
.				
19	2 + 5	13*	3 + 6	13
.				
243	10 + 9*	13	5 + 14*	19

Chart 5

Continuing, of course, to accept the reasonableness of the original time estimates, each of the activity outcomes is now assigned the probability of its occurence. This assignment is made in accordance with the assumption that the activity outcomes are independent and beta-distributed. (Chart 6) That is, the probability that the endpoints, a and b will occur is 1/6 each and that of the mode m, is 4/6. And, by multiplying the probability of each outcome within each sequence, the joint probability for each combination of outcomes is obtained. For example, combination 1 will occur once in 7,776 outcomes, combination 2 occurs four times as frequently, and combination 122 will likely occur 1024 times in 7,776 outcome.

A SAMPLE OF THE JOINT PROBABILITIES FOR EACH COMBINATION OF OUTCOMES IN THE HYPOTHETICAL NETWORK SYSTEM

COMBINATION NUMBER C_j	SEQUENCE OUTCOME PROBABILITY $P(S_{1t})$		SEQUENCE OUTCOME PROBABILITY $P(S_{2t})$		SEQUENCE OUTCOME PROBABILITY $P(S_{3t})$		COMBINATION JOINT PROBABILITY $P(S_j) = P(S_{1t})\ P(S_{2t})\ P(S_{3t})$
1	(1/6) (1/6)	•	(1/6)	•	(1/6) (1/6)	=	1/7776
2	(1/6) (1/6)	•	(1/6)	•	(1/6) (4/6)	=	4/7776
3	(1/6) (1/6)	•	(1/6)	•	(1/6) (1/6)	=	1/7776
4	(1/6) (1/6)	•	(1/6)	•	(4/6) (1/6)	=	4/7776
⋮							
19	(1/6) (1/6)	•	(1/6)	•	(1/6) (1/6)	=	1/7776
⋮							
122	(4/6) (4/6)	•	(4/6)	•	(4/6) (4/6)	=	1024/7776
⋮							
243	(1/6) (1/6)	•	(1/6)	•	(1/6) (1/6)	=	1/7776

Chart 6

Finally, (Chart 7) by multiplying each critical path time by the appropriate joint probability of that time-outcome occuring, the product of each probability and respective time for each combination is obtained. The sum of these products represents the mean expected time for the entire program. In this illustration, the mean is 13.2 time periods, as compared with the critical path time of 12 time periods.

The distribution about the mean is calculated by adding the combination joint probabilities for each combination with the same critical path time. To clarify, if we add all the probability-times for combinations with the same critical path time, say 10, we obtain the probability of the total program consuming 10 time periods. The complete distribution is as follows (Chart 8). Note that the total program may be completed in as few as 9 time periods or as many as 19 time periods. Also notice that the mode is 11 time periods and that the program is almost as likely to be completed in 17 or 18 time periods as the critical path time of 12. These surprising results are emphasized further by examining this cumulative frequency distribution (Chart 9). Although the mean program duration is 12 time periods using PERT and the true program mean is 13.2 time periods, 42 percent of the program outcomes are from 13 to 19 time periods. Of course, other networks will lead to different probability distributions (Chart 10). The vital conclusion is, however, that the most likely critical path time for a project, developed using PERT, will usually be exceeded by the true program mean, developed by considering all the likely outcomes of a project under a probabilistic approach.

A SAMPLE OF THE APPLICATION OF EQUATION VII WHICH RESULTS

IN THE MEAN EXPECTED TIME FOR THE ENTIRE PROGRAM

Combination Number C_j	Combination Joint Probability $P(C_j)$	Critical Path Time S_{ct}	Combination Products $P(C_j)\cdot(S_{ct})$
1	1/7776	9	9/7776
2	4/7776	10	40/7776
3	1/7776	17	17/7776
4	1/7776	10	10/7776
.			
.			
19	1/7776	13	13/7776
.			
.			
.			
243	1/7776	19	19/7776
	$\sum_{j=1}^{243} P(C_j) = 7776/7776$		$\sum_{j=1}^{243} P(C_j)\cdot(S_{ct}) = 102,828/7776$ which equals 13.2 time periods

Chart 7

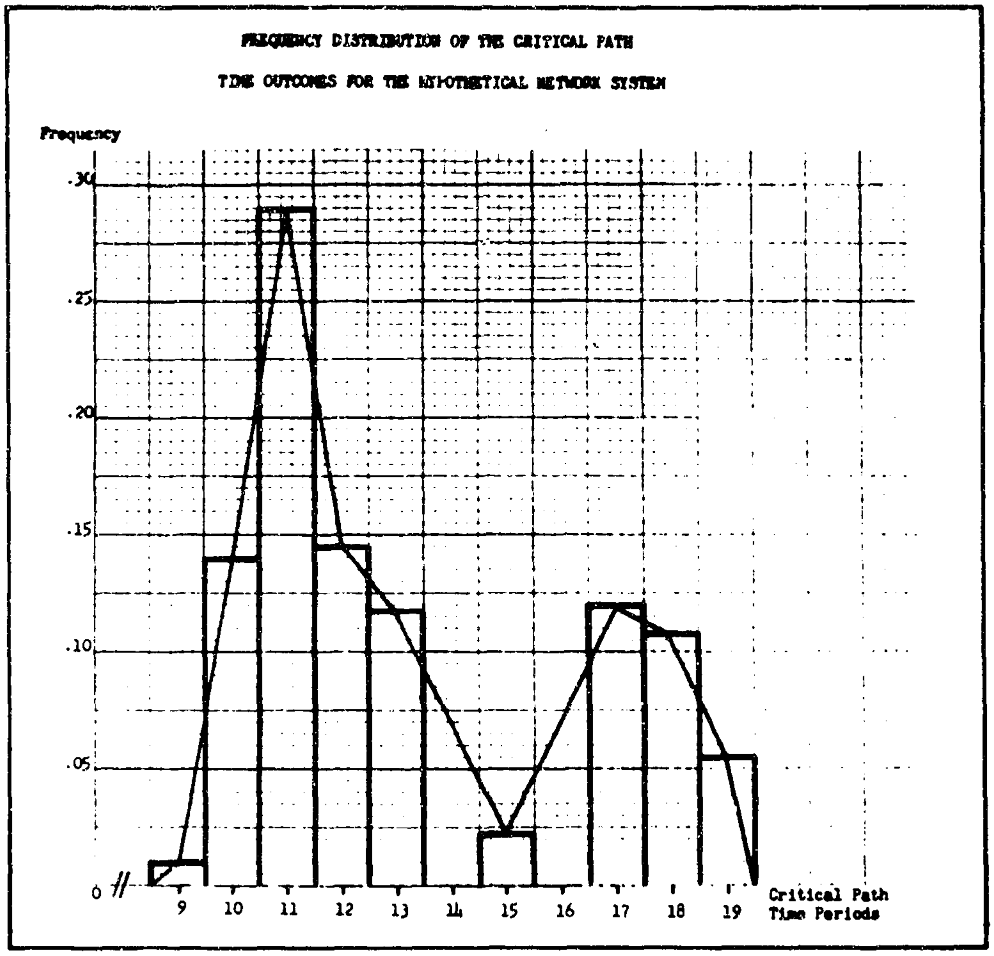

Chart 8

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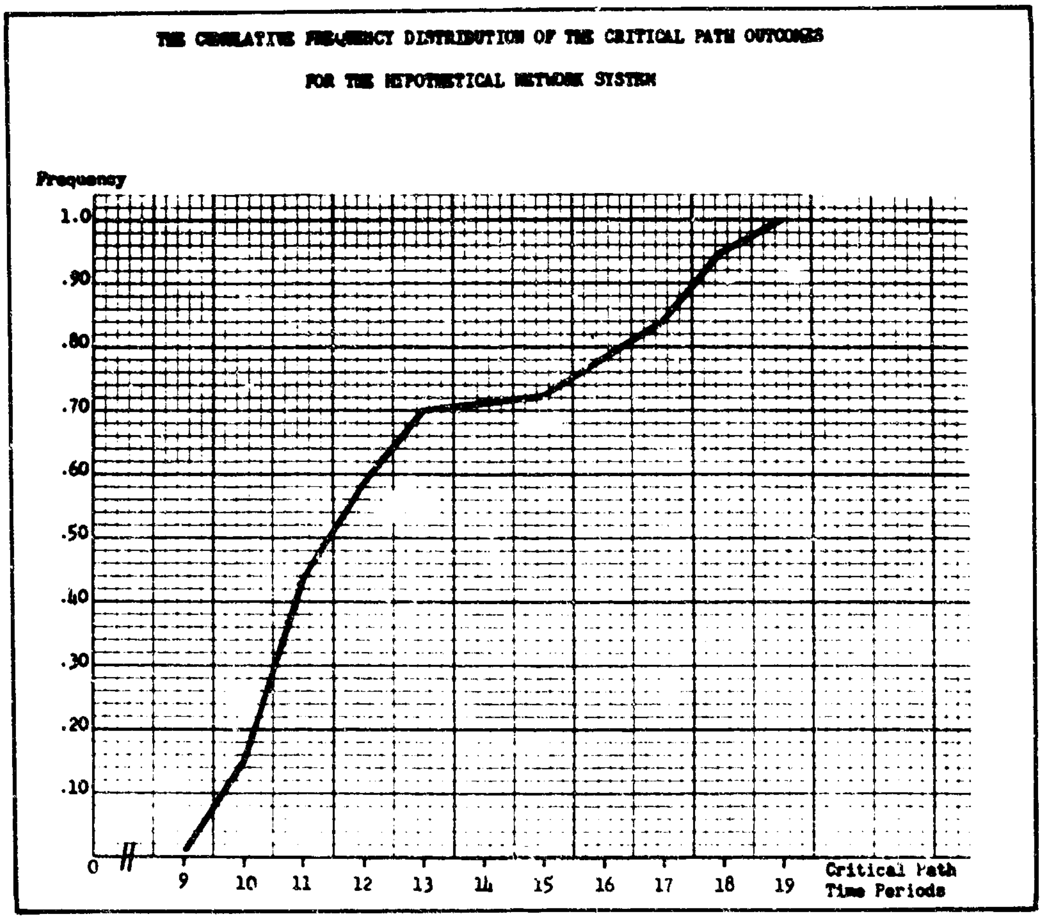
THE CUMULATIVE FREQUENCY DISTRIBUTION OF THE CRITICAL PATH OUTCOMES
FOR THE HYPOTHETICAL NETWORK SYSTEM
Frequency
1.0
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
9
10
11
12
13
14
15
16
17
18
19
Critical Path
Time Periods

Chart 9

A PROBABILISTIC APPROACH TO PERT

- CONCLUSION -

THE MOST LIKELY CRITICAL PATH TIME FOR A PROJECT, DEVELOPED USING PERT, WILL USUALLY BE EXCEEDED BY THE TRUE PROGRAM MEAN, DEVELOPED BY CONSIDERING ALL LIKELY OUTCOMES OF A PROJECT UNDER A PROBABILISTIC APPROACH.

Chart 10

As the preceding example only included five activities, a logical question is, "What mathematical problems are encountered when the network is expanded to hundreds or thousands of activities?" Freliminary investigation made by AMSAA indicates that even by using the "brute force" method the IBM 7090 computer has sufficient capability to consider all the possible outcomes and respective probabilities, and not at a cost disproportionate with the benefits to be gained.

We have presented this entire model using a time frame and not cost. This was done for ease of presentation only. Clearly, costs could be assigned to each outcome. Management can not only be provided with the distribution of possible program time outcomes but also with the range and likelihood of the total program cost.

For those of you who are interested in studying the problem further, a copy of this section of Chapter 5 will be furnished by mail upon request.

TROMOD - A COST PRESENTATION MODEL

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TROMOD is an extension of the old adage that "a picture is worth ten thousand words", and a good picture lets the beholder see both the parts and the whole. An important function of an analyst is to construct just such a picture. Through experience it can be said this is not an easy task. There are usually a multitude of variables. If values are assumed for some variables then only part of the picture remains. Flexibility is lost. The decision-maker can not vary the force structure, perform tradeoffs, or make reliable system comparisons. It is evident to AMC that Army cost data based on a specific program requires too many prior assumptions and, therefore, is *not* dynamic. Especially for a developmental system, all options must be kept open by the analyst since the system deployed may differ greatly from the system as originally conceived. The TROMOD presentation methodology *is* dynamic. By taking an incremental approach, Army input data can be compared for all systems, over a continuous range of force structures, independent of any specific force or program size. TROMOD presents cost data to the user in a rational summarized manner. TROMOD does not relieve the analyst of the fundamental responsibility for estimating, documenting and analyzing the input data.

TROMOD, basically, is a method of aggregating these standard functional categories. It is a practical model as evidenced by its successful implementation at AMC. The cost data portion of a recent multisystem air defense missile system comparison was prepared by AMC in TROMOD format. The graphical presentation of costs similar to that used for this study will be used as an example to show what TROMOD is and does.

STANDARD COST CATEGORIES

RESEARCH AND DEVELOPMENT

INVESTMENT
- FACILITIES
- ADVANCE PRODUCTION ENGINEERING
- TOOLING AND TEST EQUIPMENT
- HARDWARE
- INVESTMENT SUPPORT
- INITIAL REPAIR PARTS
- FIRST DESTINATION TRANSPORTATION
- INITIAL TRAINING
- DOCUMENTATION
- OTHER

OPERATING
- REPAIR PARTS
- POL CONSUMPTION
- AMMUNITION CONSUMPTION
- PERSONNEL
- DS AND GS MAINTENANCE
- TRAINING
- CENTRAL SUPPLY
- DEPOT MAINTENANCE
- SECOND DESTINATION TRANSPORTATION
- OTHER

Chart 1

The basic premise is that all weapon system costs can be segregated into three basic groups. The first group of costs are those that are fixed. Costs are fixed if they are incurred independent of the basic study parameters, such as quantity of hardware, time and deployment level. The second basic group of costs are those that are semifixed. These costs have some fixed qualities but also tend to vary with the size of the program. Finally, the third basic group of costs are those that are variable. They are a function of the size of the production and deployment program considered. A level of aggregation, or common denominator, has to be selected. In the case of a missile system this would likely be the battalion or firing battery.

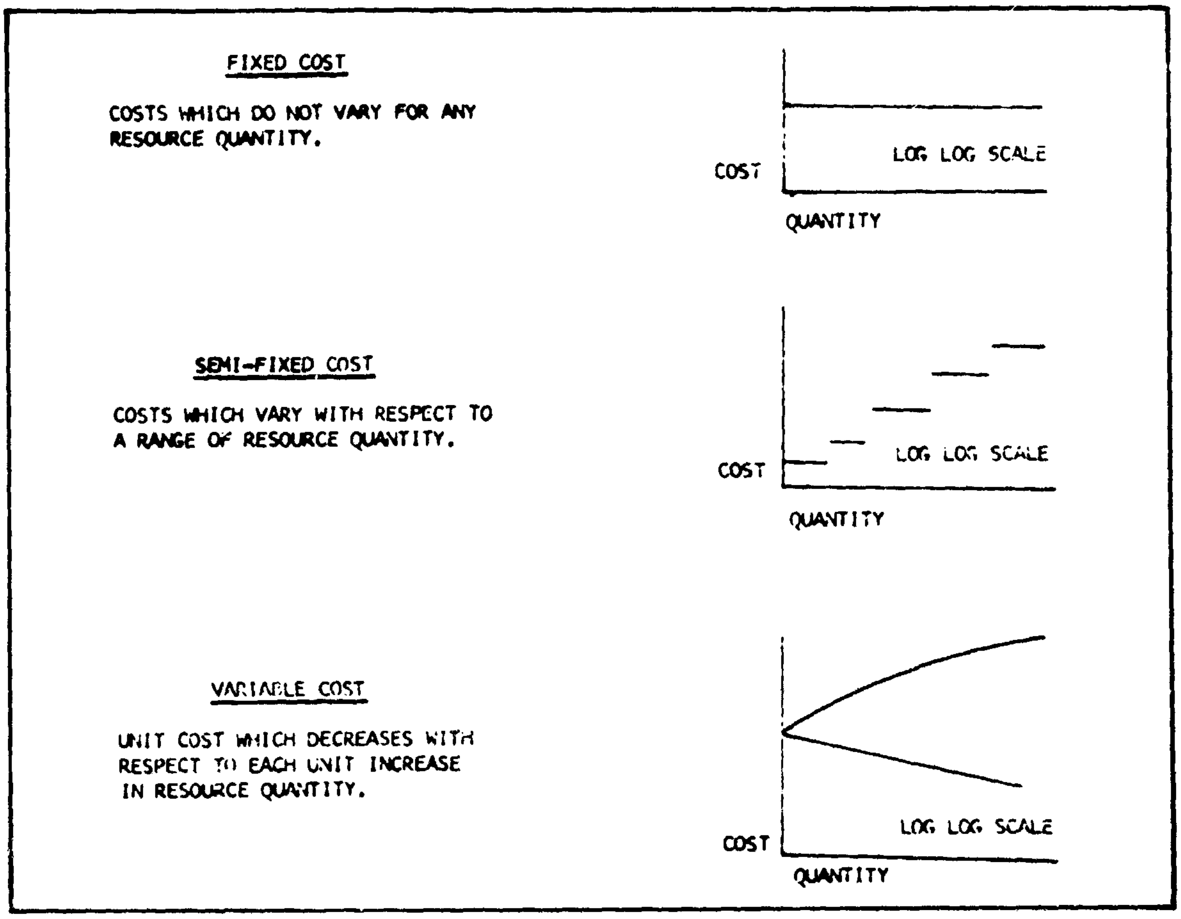


Chart 2

To cost any force structure the total tactical and nontactical requirements must be considered variable also. In this example of a requirements graph the common denominator unit, or referent, is the firing battery. A value for this referent can be selected by the user on the abscissa and the requirements for the related organizations, such as HQ and HQ batteries and GSU's are then taken from the ordinate. Note that the CONUS and overseas requirements for each organization are retained as parameters by providing separate curves for a CONUS and overseas component. The requirements information may now be easily translated into force structure costs.

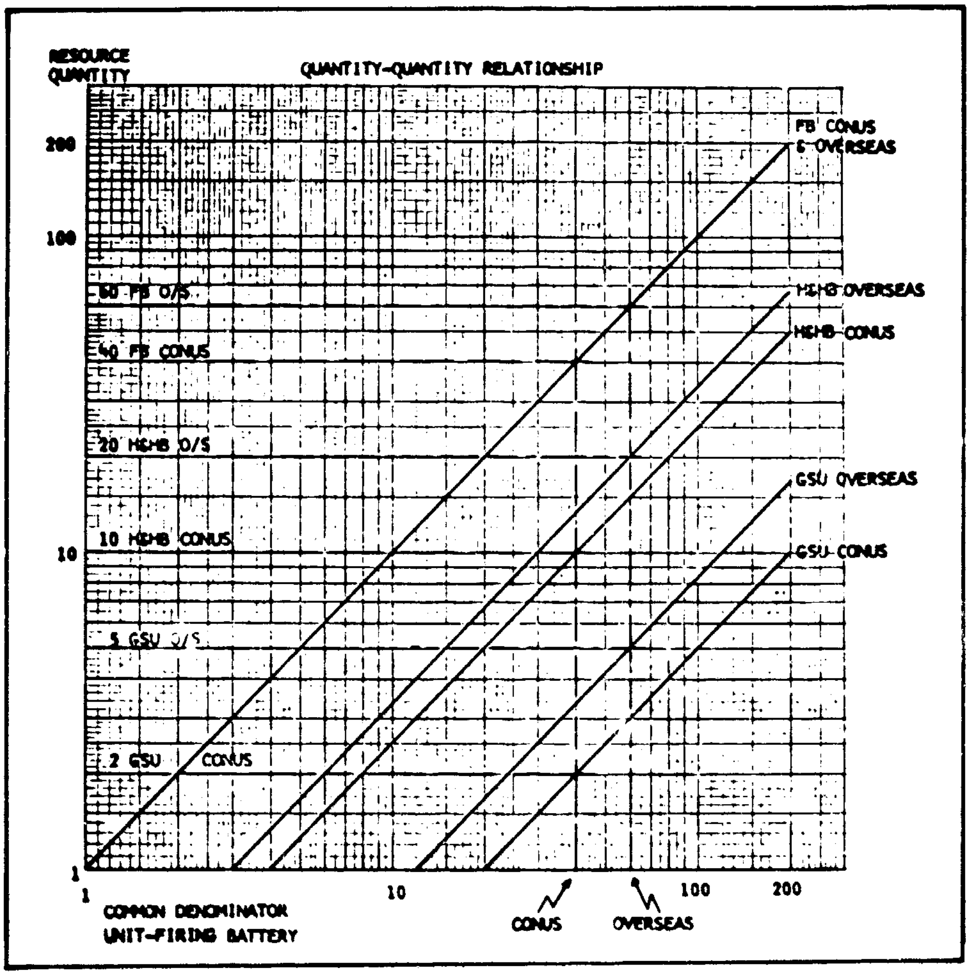


Chart 3

The fixed cost relationships, as expected, are not dependent upon force level and, therefore, may be stated as a total independent of the force level to be costed. These types of costs include but are not limited to research & development, production base support, and advanced production engineering.

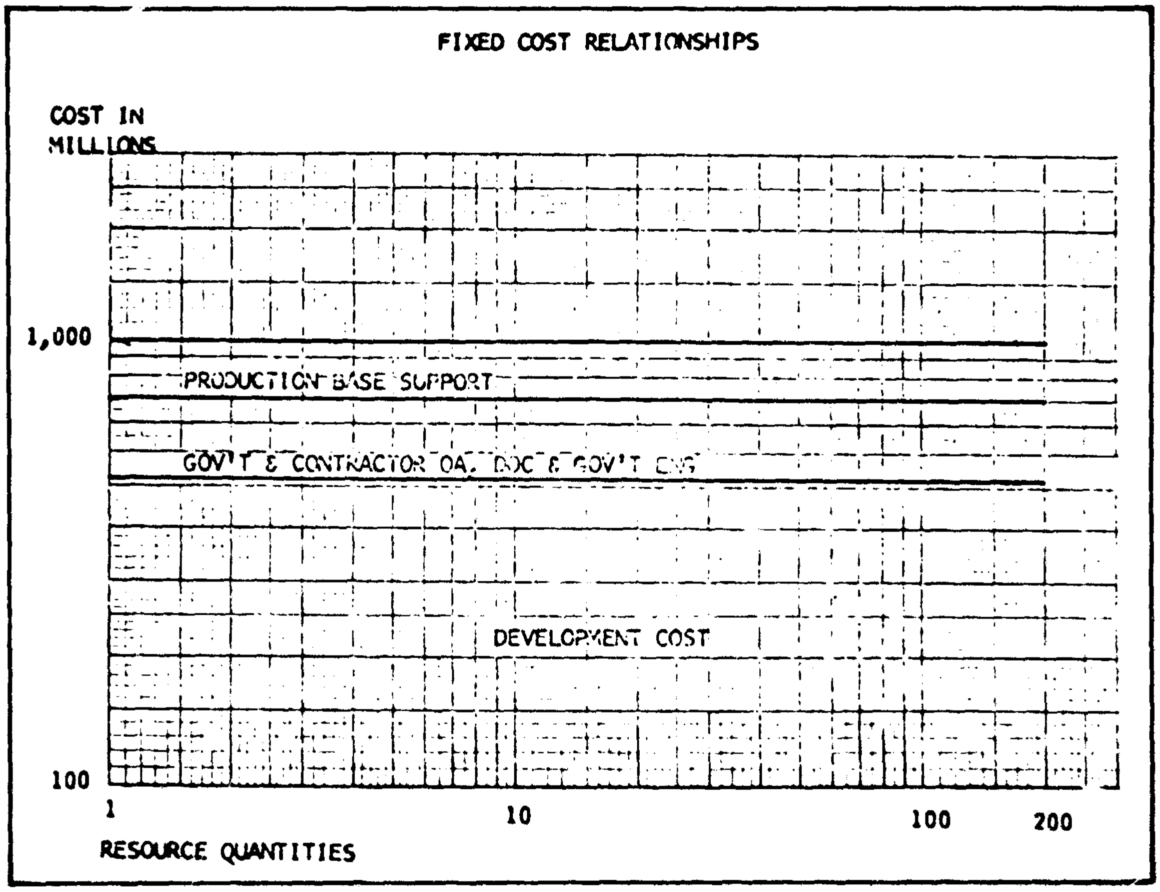


Chart 4

Semifixed costs, such as engineering, Quality Assurance (QA) and documentation, are not easily expressed as a continuous cost-quantity function since these costs are time and program oriented. They are more dependent on the yearly production periods as determined by the size of the program and the production rate. This graph shows a practical approximation of a whole series of possible investment support programs. These curves represent the cumulative build-up of other investment support as the programs get longer due to larger total deployments.

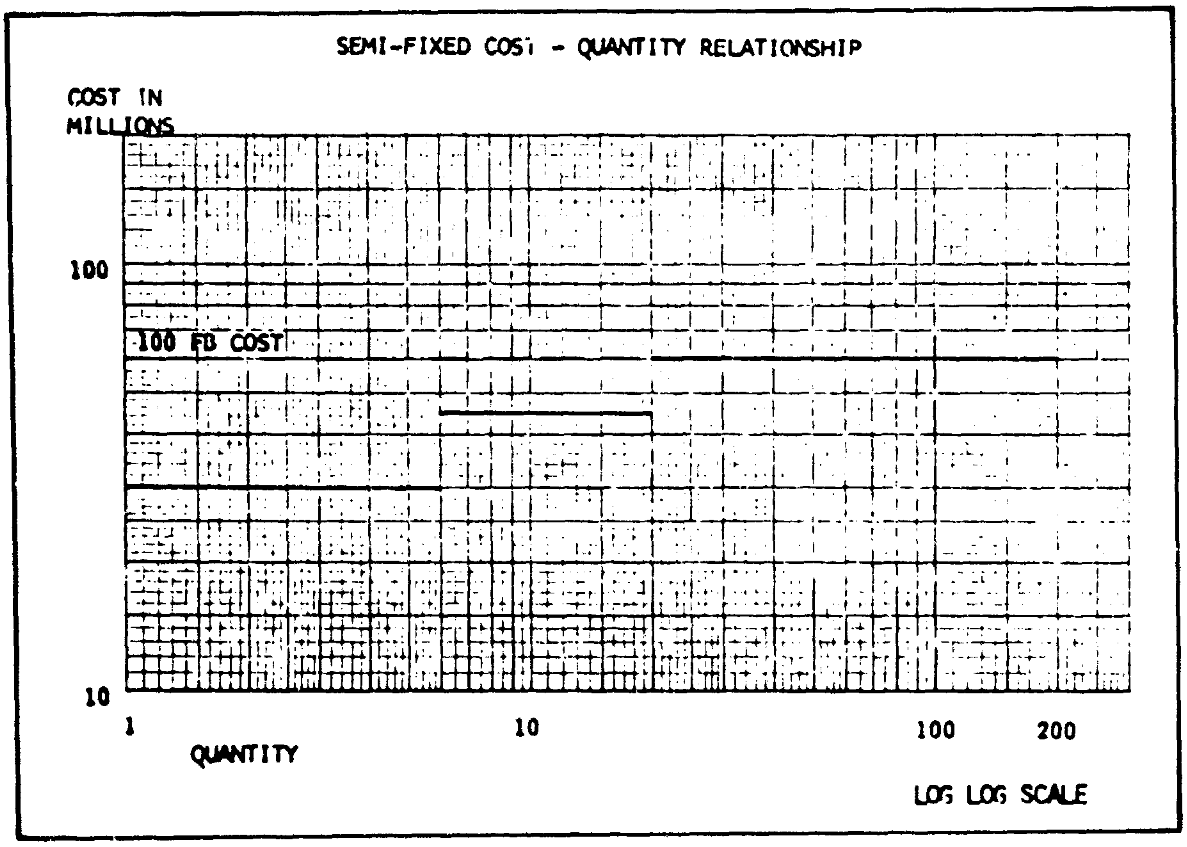


Chart 5

Aggregation will now be illustrated for the so-called variable cost relationships. The hardware cost is a variable cost/quantity relationship most likely estimated as a theoretical first unit cost and learning slope. The hardware components in a battery, through the process of a nonlinear transformation, are plotted as a cumulative cost curve for battery equipment. The user can then read the total cost for the desired deployment directly from this curve. The transformation to these curves is not simple since the cost/quantity relationship for each component is based on a learning curve. Another problem arises because both major and minor battery equipment enter the battery in varying ratios. Furthermore, requirements exist for this same equipment in other uses, such as table of allowance and maintenance float. Proper determination of the fully allocated cost of an incremental TO&E unit dictates that total resource requirements be expressed in terms of the common referent, which in this example is the TO&E battery.

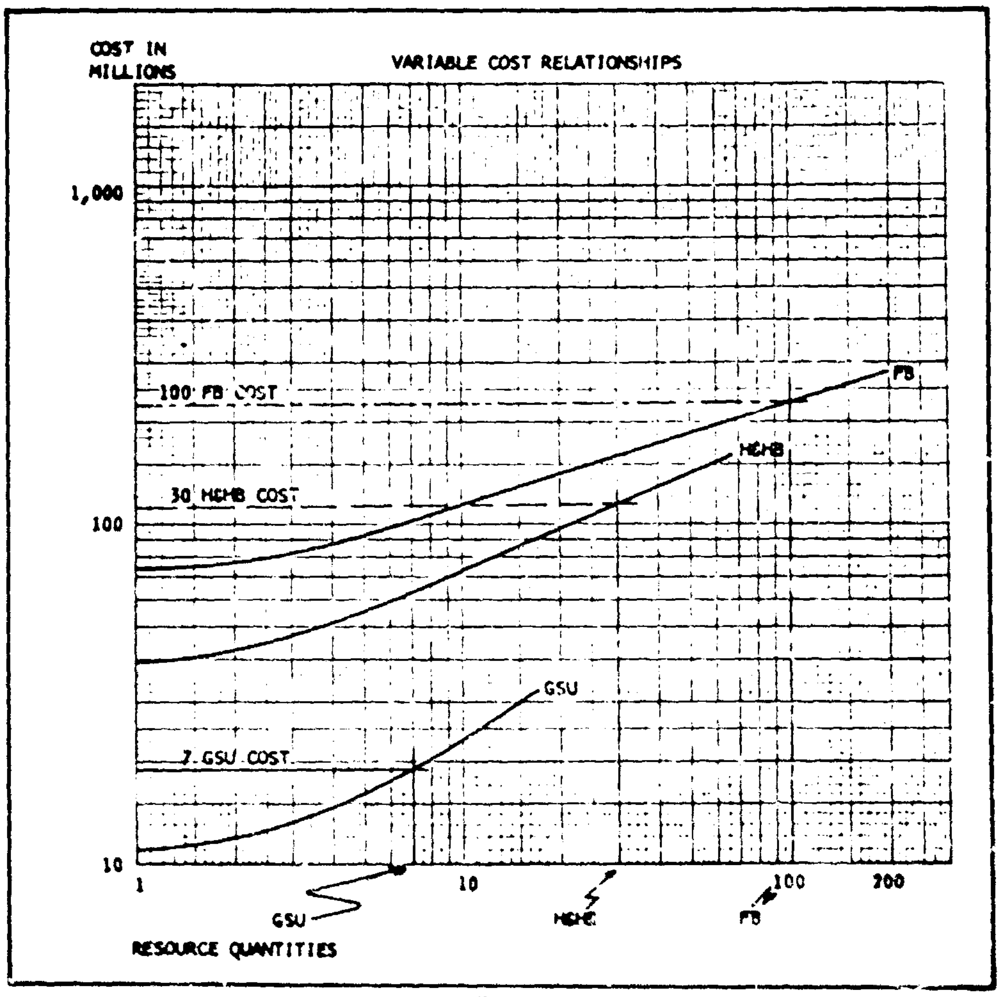


Chart 6

The TO&E batteries deployed are shown here on a log scale from 1 to N, where N can be any number representing the maximum possible deployment for the system. Table of allowance and maintenance float requirements are shown on the second and third scales aligned with the common referent to show the point at which each is required irrespective of time. The sum of these three scales is an expression of the total production requirements in terms of the common referent. The time scale indicates the period required to achieve the desired deployment. This scale may be stretched or collapsed, of course, by varying the production rate of the system peculiar equipment. The check points are used as reference points to align the completion of the development program with the production and deployment program, so that segments representing program years may be identified. At the availability date of the first 4 TO&E batteries, 10 battery equivalents must be produced the 4 TO&E, plus 5 for TA use, and 1 for MF use.

DEPLOYMENT RELATIONSHIPS

(LOG SCALE)

TOE BTYS DEPLOYED		-	1	2	4	4			72	120		N
TA BTYS		2	3	4	4	5			18	20		n'
'MF		-	-	-	-	1			10	15		n''
TOTAL BATTERIES PRODUCED		2	4	6	8	10			100	155		n'''
TIME	0						1	2	3	4	5	
CHECK POINTS				X		X						

Chart 7

To equip these batteries it will be assumed that 10 units of hardware component A, 9 units of component B. and 27 units of component C are required. From the respective cumulative average unit cost learning curves, the appropriate average unit costs are multiplied by the previously determined total requirements for each component. Summing the costs of these requirements gives the hardware cost portion of the first four tactical batteries. This aggregated hardware cost is plotted on the variable cost graph at the fourth TO&E unit. Basically, this whole procedure is a nonlinear transformation from both quantity and time to a common referent, in this case the TO&E battery. Similar iterations up to the maximum possible number of TO&E batteries, N, derives the cumulative total hardware cost curve for battery equipment shown earlier.

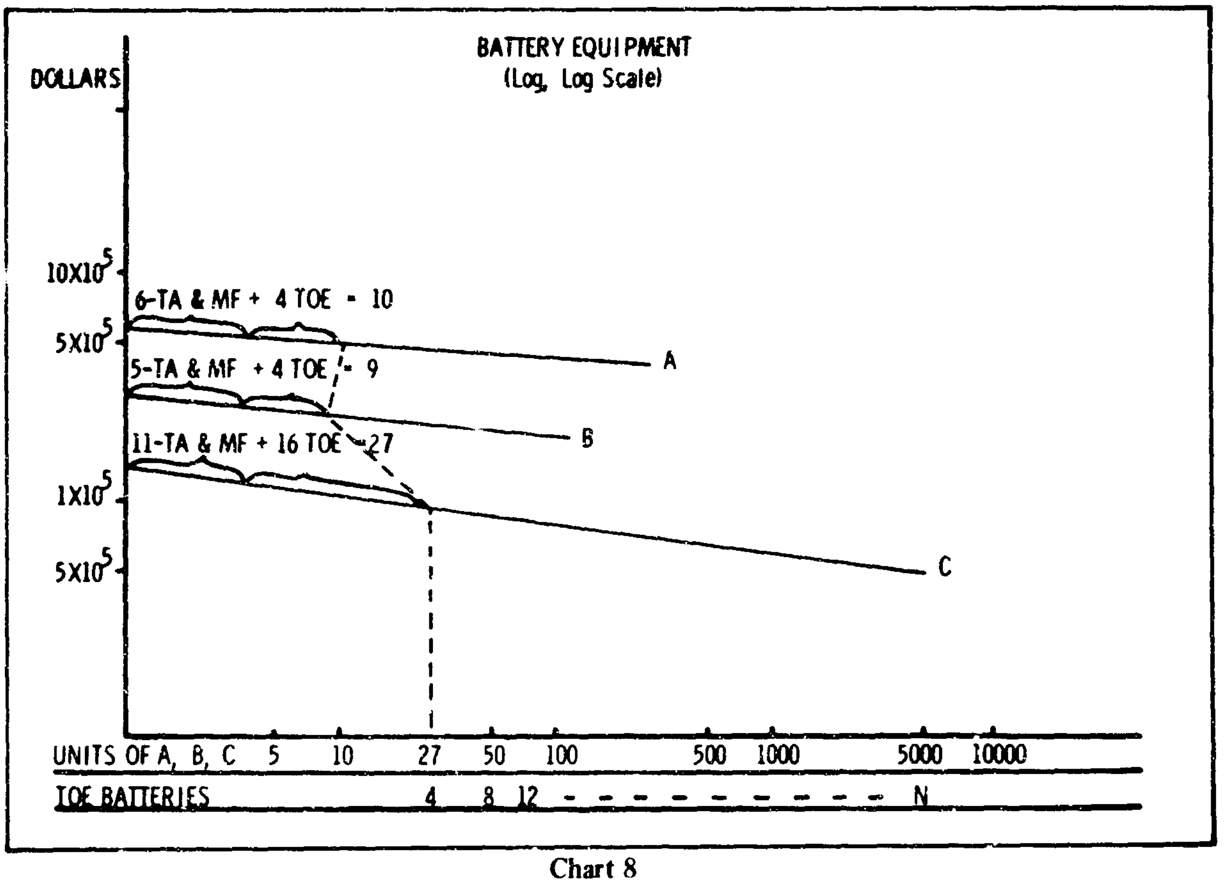
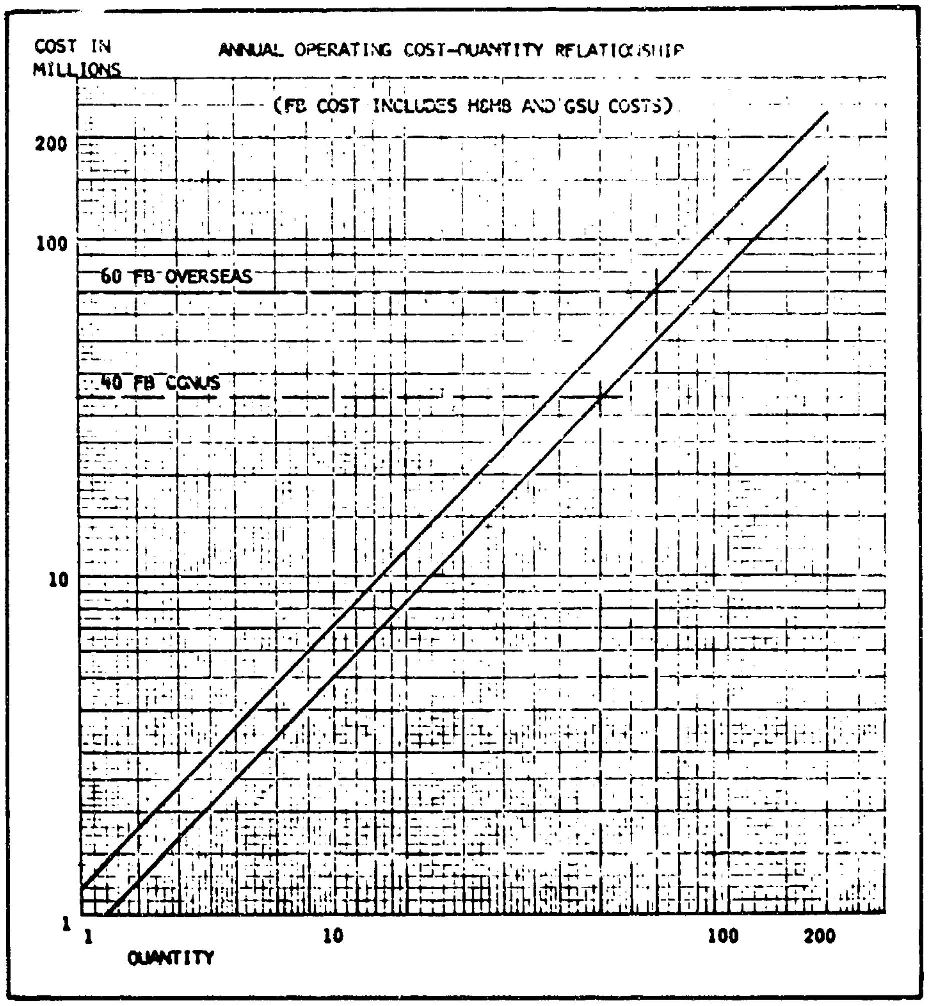


Chart 8

Annual operating costs may be easily expressed as a function of the number of organizations deployed. These costs are for operation after the desired deployment level is reached. It is also necessary to state the operating costs for operation of those tactical and training batteries deployed during the transitional production and deploying period. Conceptually this transitional operating cost is represented by the area under these annual operating cost curves for each organization for the average number of units deployed in the transitional period. By cumulatively integrating for the area under each segment of this composite cost curve, a series of points are derived which describes the cumulative composite operating cost curve. The operating costs of the transitional period can be read directly from this new curve also at the point on the common referent, which describes the desired deployment level. This operating cost represents the cost of operating the average number of batteries deployed in the transitional deploying period, however long that period may be.



COST IN MILLIONS
ANNUAL OPERATING COST-QUANTITY RELATIONSHIP
(FB COST INCLUDES HGHB AND GSU COSTS)
200
100
60 FB OVERSEAS
40 FB CONUS
10
1
1
10
100
200
QUANTITY

Chart 9

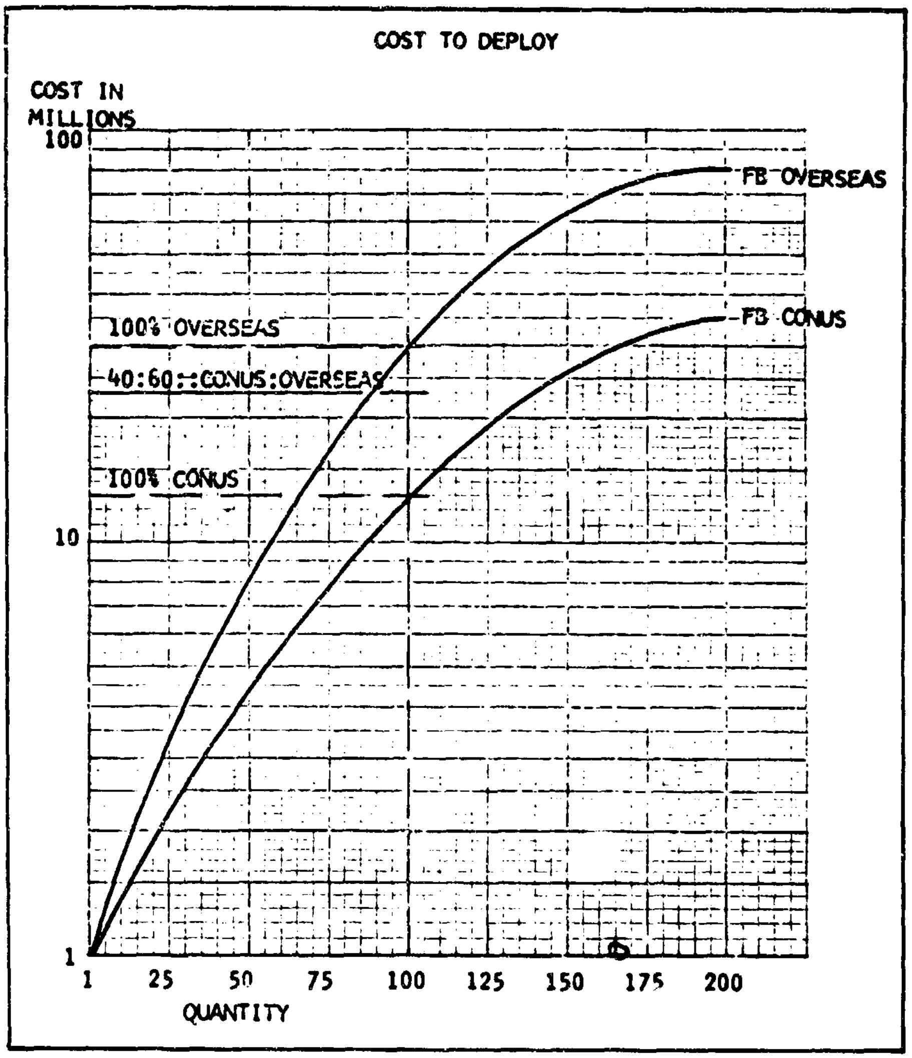


Chart 10

The costs from all these curves are entered on a summary sheet as shown and summed by system. The total of all costs on this sheet includes costs for the force structure as specified by the analyst or other user. This completes the illustration of how TROMOD is developed. There are some refinements and applications which have not been discussed but are included in the concept.

COST ESTIMATING FORM					
FIXED COST				$ (M)	$ TOTAL (M)
				1,100.0	1,100.0
ORG UNITS	QUANTITIES		TOTAL QTY	VARIABLE COST	
	CONUS	OVERSEAS			
FB MCMB CSU	40 10 2	60 20 5	100 30 7	225.0 115.0 19.0	359.0
ORG UNITS	% OF FORCE LEVEL		CONUS % OF TOTAL DEPLOYED	OVERSEAS % OF TOTAL DEPLOYED	
	CONUS	OVERSEAS			
FB	40%	60%	5.2	18.0	23.2
ORG UNITS	QUANTITIES		CONUS OPERATING COST PER YEAR	OVERSEAS OPERATING COST PER YEAR	
	CONUS	OVERSEAS			
FB	40	60	32.0	72.0	
TOTAL OPERATING COST PER YEAR $ (M)				104.0	
TOTAL OPERATING COST PER YEAR X 10 YEARS OF OPERATION					1,040.0
SEMI-FIXED COST FORCE LEVEL 100					60.0
TOTAL COST OF FORCE LEVEL 100 CONUS/OVERSEAS RATIO 40 / 60					2,582.2

Chart 11

Two of these bear mention. First, any organizational unit may be used as the common referent, such as the fire unit instead of the firing battery. In fact, if only a single weapon system is being studied major items, such as trucks or tanks, could be used as the common referent. Secondly, TROMOD can and has been expressed analytically. Equations have been written for each type of curve shown. This makes it possible to estimate the total cost of a specific force structure with only the basic study parameters and cost estimating relationships as inputs. The graphical display shown here permits some visual sensitivity analysis and complete flexibility in choice of force structure components. This same summary could be obtained from summation of the analytic expressions if desired, without preparation of the graphic display. In the actual missile study mentioned earlier, AMC was asked to cost approximately 50 force structure combinations using TROMOD graphs as described. Each took just a few minutes. This form of flexible, timely response permits the systems analyst to consider a wide range of force structures over a short period of time. A graphical presentation may not seem to be the most precise way to determine costs required for a programming exercise, but the ease of costing any force structure using any set of study parameters is a big advantage over any preciseness lost, especially when the estimating accuracy on developmental systems is admittedly not too good. This is a good example of what the previous speaker, Dr. Enthoven, has been attributed to say, "It is better to be roughly right, than exactly wrong!"

To summarize, the advantages of putting a cost study into the TROMOD format are numerous and important ones. Using the graphic medium described here, only a few sheets of paper are required to present all the costs, in total, which are of significance to the system being studied. The one page summary includes all of the research & development, investment and operating cost categories. The graphs show how total costs change if incremental organizations, such as a fire unit, are added or subtracted from the force structure. Flexibility is provided to vary CONUS and overseas deployment mixes. The complete TROMOD graphically presents all of the cost detail for each system on no more than a dozen sheets of paper.

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A PANEL FROM
THE RESEARCH ANALYSIS CORPORATION
CONSISTING OF

Mr. Frank A. Parker, President
Mr. Lee S. Stoneback
Mr. Conway J. Christianson
Dr. Harrison N. Hoppes

It's been said that logistics, like politics, is the art of the possible. Logistics has probably never been solely an art and, while it does not qualify as a science either, it certainly has been the object of the application of increasingly sophisticated techniques of management.

The role of the systems analyst in the search for ways to improve logistic responsiveness has been a vital one, and continues to be, if measured by the scope of current efforts. The 1968 *Army Logistic Study Program* lists 162 planned, in-progress, or recently completed studies that involve hundreds of man-years of work covering every conceivable aspect of logistic operations. These efforts, plus the deliberations of such special groups as the Baker Board and the Brown Board have produced a multitude of recommendations and suggestions for corrective action.

Research Analysis Corporation has, of course, had a part in this work. Those of you who are familiar with this work know that the nature of the assistance we've provided has varied greatly, ranging from such simple remedies as changes in the criteria for addition and retention of items on stockage lists at combat unit level, to the more complex analysis leading to changes in the overhaul and replacement policy for Army vehicles. It is difficult to quarrel with a program that has produced useful results, and one cannot quarrel with a program that has dealt with the client's problems of immediate concern and urgency, given the mission of supporting forces stationed in various parts of the world, a large part of them in a shooting war, and given the budget limitations that constrain research efforts.

But all things are relative, and it is always difficult to measure the magnitude of the improvements resulting from these studies. Many studies, in our judgment—and this includes some conducted by RAC—do not appear to have brought the improvements expected, for the system continues to be plagued with difficulties. Sometimes the lack of impact can be traced to pitfalls that the analyst has fallen into—pitfalls that are much easier to identify in hindsight than during the course of a study. Sometimes it can be traced to the origin of the study, that is, in the client's diagnosis of a problem. In any case, it seems appropriate to question whether research resources are being used to best effect.

We could talk at great length on what we think the scope and character of logistics research should be, but we shall restrict ourselves to a limited treatment of four topics. These are, first, the matter of problem identification; second, the relative emphasis on long- and short-range problems; third, what we call the interaction between data inputs and models; and fourth, measures of performance or effectiveness.

What do we mean by problem identification? Essentially, it is a matter of choosing the right objectives. This can be crucial. It is far more important to choose the right objective than it is to find a perfect optimization procedure or make the right choice between alternatives. The choice of the wrong alternative may merely mean that something less than the best solution is recommended. But the choice of the wrong objective means that the wrong problem is being addressed. In other words, deciding what *ought* to be done has to come first; determining *how* to do it can follow. The tendency all too frequently is to accept the client's original statement of what is wrong or wanted, and then to set about building a model and gathering data, scarcely giving thought to whether the problem is the right problem or how the answer will contribute to the decisionmaking it is meant to assist.

Let me cite two examples of direct interest to AMC, one from our recent experience. A few years ago we were asked to devise a method for forecasting repair parts requirements more accurately. Implied was the assumption that repair parts were in fact procured in accord with forecasts and that shortages at user level were, therefore, attributable to poor forecasting. Recent findings indicate, however, that current forecasting may be basically sound and that the unavailability of parts must be attributed to other causes, as, for example, the problem of requisitioning wrong numbers or failure to procure in accordance with the forecasts developed. It appears, in other words, that a wrong assumption led to the identification of the wrong problem.

It's quite possible that some of our other work in the supply and maintenance field is also improperly focused. In much of this work we have addressed problems rising from the use of conventional existing equipment. Research in this area, exemplified by the work on life cycle management, has certainly produced useful results. But these studies have been done in the context of prevailing organization, equipment, and procedures. That is, they take the existing organization for granted, without questioning it. Perhaps the entire concept should be challenged, and the more basic or root problem of the interaction of supply and maintenance on the one hand and equipment design on the other should be addressed. One route of investigation, for example, might be the consideration of the design of equipment for discard upon failure.

In both of these examples proper diagnosis is at the heart of the problem. Both are examples of a tendency to treat a malfunction or shortcoming as a basic problem, whereas it may merely be a symptom of a more deep-seated defect, the signal for a more far-reaching system analysis.

Concentration on a symptom can easily result in limited-objective, product-improvement recommendations that have little impact on the logistic system's performance. The logistic system has demonstrated an uncanny ability to absorb such minor innovations and to appear no different, performance-wise, after the initial change has worn off. For example, over the past several years the repair parts supply system—one of the most troublesome aspects of logistic operations—has managed to assimilate countless organizational, procedural, and mechanical innovations with little measurable improvement in overall performance. In terms of mechanical innovations, for example, we have installed computers at our inventory control centers, card-processors at our support units, and transceivers to tie these machines together. And still the system is not as responsive to the needs of its customers as we think it should be. In some theaters there has been only minor improvement; order and ship time, initial-fill rates, and deadline rates are not significantly better than they were 5 years ago. This does not mean that the systems analysts did not or cannot make contributions that will improve repair parts supply. In most cases it is almost certain that supply performance would have deteriorated further if the improved procedures had not been adopted. In many cases, however, it is extremely difficult to determine what effect on supply performance a given change produced because concurrent changes tended to mask or degrade the impact of the particular change of interest. In others, the benefits derived from a change could not be measured because they were dwarfed by the large fluctuations in supply performance that are inherent in the supply system as a whole. In any case, the inclination to treat merely the symptoms of more basic problems and the tendency to specify in detail precisely what should be examined places an unnecessary burden on the client and, likewise, an undesirable restraint on the researcher.

What I have just said relates directly to the matter of the relative emphasis on research of short- and long-term problems. On this subject three questions require consideration:

1. Why do short- rather than long-range problems tend to dominate study programs;

2. Why is it important to focus greater attention on long-range problems; and

3. What are some of the conditions for studying long-range problems?

First, it is important that we attempt to draw a distinction between short- and long-range problems. We have found that attempting to classify problems as short-, mid- or long-range is an exercise in frustration; problems tend not to fall neatly into 5- or 10-year time brackets. We believe, however, that they can with some degree of utility be categorized as short- or long-range. For the purposes of this discussion short-range problems are defined as those that relate to the Army forces and systems described in the 5-year defense program, while long-range studies are those that cannot affect the 5-year program; i.e., they are concerned with the next generation of systems and new doctrine for their employment.

What has been said about problem identification bears very directly on the matter of the relative emphasis that should be given to research on short- and long-range problems. Because of the tendency to identify the problems to be analyzed on the basis of past experience or intuitive judgment instead of undertaking systematic indepth analysis and, therefore, to mistake symptoms for more basic deficiencies, and because of the resultant tendency to examine too small a piece of the total system, we are too often preoccupied with patching up the existing system and with developing suboptimum solutions.

There are many reasons for this focus on the shorter range problems. They stem from the day-to-day pressures experienced by those who are called on to make existing systems perform better; they are surfaced by the pressures emanating from the war in Vietnam, as well as those emanating from the requirement to support forces in being scattered over virtually the entire globe; they stem from budget limitations; and they stem from the fact that they are here and now -they are immediate and difficult, if not impossible, to ignore.

Conversely, long-range problems are difficult to identify and even more difficult to understand and define in sufficient detail to gain acceptance and get a study launched. Long-range problems have one other very significant characteristic: they are not here and now; they seldom have an aura of immediacy; and thus, during periods of stress and limited budgets, they can be deferred.

It is because of the existence of continual pressures which tend to force the focus on immediate problems, that we are concerned about the balance between the short- and long-range, and emphasize the urgency of insuring that a greater portion of the limited resources available be directed to the study of long-range problems.

There is a need in many instances to examine the larger mission, to take a true systems approach. Questions must be asked about the probable nature of future conflict environments, the Army's deployment posture, and the implications for logistic support requirements. Most important is the need to determine what a system must be able to do rather than what the system can do. An uninhibited examination of requirements is likely to challenge policies that for years have been accepted without question and seemed to be inviolate. Improvements in communications, and data transmission and storage, for example, may make highly centralized control of supply not only possible but unavoidable and indeed necessary. Approaching the problem from a requirements point of view, for example, may give air transport a role quite different from the one conventionally assigned it - i.e., merely as an adjunct or supplement to the surface transportation system, under which its full potential is not exploited. No policy or principle should be immune from challenge simply on the basis of age or habit. The multi-echelon depot system, for example, may very well be inconsistent with both the needs and capabilities of a future logistic support system.

The implication of such approaches is almost unavoidably a long-term study, for it entails examination of different concepts of support—concepts that probably can be examined and tested only through techniques or tools not yet devised—or by such techniques as simulation, which need to be further developed or expanded.

Further, these long-range questions need to be addressed by analysts who are not inhibited by identification with or who automatically accept existing policies, practices, and principles. General Johnson, the ex-chief of staff, recently commented on the difficulty of getting logisticians to examine critically their own house. For example, most logisticians cannot address the question of whether depots are required in a theater of operation, because it may not even occur to him that alternatives are possible. What we are attempting to emphasize is the need for uninhibited thought and untrammeled study of problems with at least these three specific conditions: first, that the problem not be defined in specific detail or with narrow bounds, but rather that the researchers be given latitude to grapple with, to define, and redefine the problem as necessary to ensure that the real problem is in fact identified; second, that the research be accomplished in close coordination with the Army but in an uninhibited environment; and third, that the problem be addressed in a time frame sufficiently forward of the present as to ensure that the best alternatives have not been foreclosed. It should be noted here that one of the serious shortfalls of research on current systems and immediate problems is that often there are no meaningful or real options to the status quo. It is only when we move out to the future that we have the opportunity of choosing from among alternatives and thus influencing our future course in a meaningful way.

It appears appropriate to add one more observation on why long-range problems do not tend to surface in the normal course of events. Long-range problems tend to encompass whole new concepts or systems, or a whole new set of policies and procedures; thus, these problems cut across several areas of responsibility—they transcend normal staff and even command lines. Unlike the short-range problem of limited scope, the long-range problem does not fall within the province of one functional element of the command. Its importance, then, has to be recognized, with some degree of concurrency, by perhaps several functional elements of the command.

An operating command, such as AMC, geared to day-to-day momentum and pressures of supporting forces all over the globe, is not an environment conducive to either the identification or definition of many potential future problems. We in the research community believe that we have the responsibility, as well as the opportunity, to be of major assistance to you in the identification and definition of such potential future problems.

On this matter of long- versus short-range research we would like to leave you with these three thoughts:

First, we believe that short-range problems tend to dominate the Army's study program. On balance, not enough attention is given to long-range problems.

Second, we believe that it is in your best interest to ensure that a greater portion of the limited study efforts available are directed to the study of long-range problems. Short-range research, because it deals with the deficiencies of the existing system, tends to inhibit original thinking and imagination with respect to new concepts. It tends to be restricted to today's technology and yesterday's organization, and to foreclose consideration of radically new proposals for coping with circumstances that are expected to obtain some years in the future. Long-range research, on the other hand, at least permits the researcher to free himself from the lag behind technological advances and to conceive the new concepts and systems that either permit the exploitation of technological innovations or inspire new innovations.

Third, we believe that while the responsibility for the identification and study of potential future problem areas is yours, we in the research community share that responsibility. We believe also that we can play a very important role in this area. We stand ready to accept ever greater opportunities and challenges to work with you in the solution of your future problems in which we have a common interest.

Long-range research inescapably concerns problems that are characterized by uncertainty and systems that are years from actual implementation. The technique that analysts have turned increasingly for such research is modelling. A model, as an abstraction of a part of the real world, can take many forms. We are concerned here with requirements for the more sophisticated simulation models and gaming models needed in long-range systems studies.

The value of models as research tools lies in that they provide a systematic framework for comparing alternative choices in the light of costs or possible outcomes, and for applying the judgment of specialists to problems that yield only partially to quantitative reasoning. In serving these purposes they can also help in the identification of problems.

But models have their limitations. That this is not commonly understood is indicated by the comment one frequently hears, "We already have a model, why do we need another?" The answer is that in the present state of the art models seldom represent all aspects of reality. Any single model will have limited capabilities, its form depending on the questions to be asked of it. Depending on the kinds of questions to be asked and the degree of detail desired, a whole set of models may be called for.

On the other hand, a model, or even a set of models, will not suffice either. Prerequisite to the efficient and fruitful use of models in either the choice of, or improvement of, a system is an understanding of the way in which the system actually operates and, beyond this, the availability of input data that will give realism to the research.

A recent AMC-sponsored study of the repair parts system illustrates our approach to a study involving the use of a model. We undertook this study nearly 3 years ago. One of its objectives was the development of a simulation that could be used to evaluate alternative repair parts supply policies, procedures, and organizations. We began the study at the user end of the system, and moved up through division, corps, army, communication zone, and the NICPs. Emphasis was placed on obtaining first-hand knowledge of supply practices, procedures, and performance under actual field conditions. We moved up to the next echelon only after we were reasonably certain that we understood the operation at the lower echelon. This approach, while time-consuming, had the advantage of always starting from a firm base with practical experience and valid inputs. It took two years to cover all echelons, and about half of this time was spent in the field. The development of the model began after we had covered the division level.

The first model developed was a relatively simple two-echelon affair. The model builders in this case not only had the benefit of first-hand experience, but could also avail themselves of the experience of the entire team. Conversely, the model builders could make known any data requirements that developed and that the field team might have overlooked. As a result, we now have a simulation model in operation that covers all echelons.

A few examples of our findings about the repair parts supply system will demonstrate the need for a good understanding of a system before attempting to model it. The foundation of today's repair parts supply system is the availability of demand data. If we know, for example, that 100 hub caps were used in a given time period, this information provides the basis for establishing the stockage requirements for this item for a comparable future time period. This is the theory. We found, however, that at user level half of the demands never were recorded. At the direct support level 25 percent were not recorded. The so-called fringe demands almost never are recorded, and therefore seldom qualify for addition to the stockage list.

It also was found that the stock records clerk's arithmetic in calculating stockage requirements was in error about half the time. Under these circumstances requirements determinations obviously will always be understated.

Certainly one of the most important evaluation criterion for a supply system is how well it responds. Our data showed that it took an average of 5 days to obtain fill on a high priority request when the part was available in the division; time-to-fill from sources outside the division averaged 22 days.

We were able to measure the magnitude of the delays and to identify where the delays occurred in the order and ship process, but we still have difficulty in reconciling why response to requests takes so long. And beyond the time-to-fill factor, it is also significant that about 45 percent of the requisitions never get filled, at least within the time that we were able to observe. A substantial number of unfilled requisitions resulted because units were asking for a federal stock number that was unrecognizable by the supply system. At the time of our analysis about one out of four requisitions was a bad number. There were several reasons why this happened–simple clerical errors, where two digits get transposed, out-of-date manuals, etc. Unfortunately, using units were not aware that they had submitted an invalid requisition and sat back patiently hoping that someday they would be supplied.

Such facts of life simply emphasize the need for the model builder to know the real world, to know the distortions of the system as it actually operates. Without this he runs the risk of making improper assumptions and of engaging in a purely academic, ivory-tower exercise.

The model itself and knowledge of how a system actually works are two aspects of research employing models. The possession of adequate input data is the third essential leg of the research stool. Empirical data on the operating system will ensure a greater degree of realism and, therefore, inspire more confidence in the results of the analysis. Data-gathering is often a grubby, time-consuming task. Unfortunately the researcher has no cut, for if there are no ready-made data available, he will have to develop a plan for obtaining it. On the other hand, data-gathering can not be carried on in a vacuum, unrelated to the function of analysis itself. The collector must know what use is to be made of the data and, therefore, must be the judge of their adequacy.

For the past few years the Logistics Department at RAC has been building a tape library of logistic data for use in its research; this has been a very useful resource. At the present time we have approximately 1000 reels in this data bank. The size of this bank is likely to lead some to the conclusion that we surely must already have all the data we can possibly need for the analysis of logistic problems. But the usefulness of these data is relatively short-lived. They must be continually replenished and brought up to date. Moreover, needs cannot always be foreseen, and the requirements of a particular study or model necessitates new data-gathering efforts to meet the special needs of the particular study. Data-gathering, therefore, is a never-ending job.

This brief presentation is intended to point out the value of modeling as a tool in addressing long-range logistic problems and to note some of the implications of using this technique, particularly with respect to the data inputs that are essential to the fruitful use of models. Although reality can never be fully achieved with this technique, a model can be extremely useful in understanding related functions and in evaluating alternative systems. Indeed, models have become indispensable tools in the conduct of research on long-range problems. One should not expect too much from them, however, nor be surprised at the necessity for constructing different models for different purposes. And one should keep in mind the importance of achieving a thorough understanding of the operation of a given system and of acquiring the data that can provide realism in model employment.

Closely related to the subject of models is the problem of devising logistic effectiveness measures. In fact, models and effectiveness measures are complementary elements within many systems analyses. Models provide the analyst with a means of measuring effectiveness.

Other means of measuring effectiveness such as observing the operation of the current logistic system are, of course, also available. Having decided upon a means of measuring effectiveness, however, we still must select the specific effectiveness measures, such as deadline rates or initial fill rates, that will be used to indicate our logistic posture at any point in time or our performance throughout time. For our systems analysis efforts to lead to productive logistic decisions, we must not only employ adequate means of measuring logistic effectiveness but adequate effectiveness measures as well.

During the remainder of this presentation two thoughts will be developed. We need to improve our current measures of logistic effectiveness, and there are many fertile opportunities to use the improved effectiveness measures to monitor logistic operations.

Over the years systems analysts have found the measurement of combat effectiveness to be one of the most promising, and yet one of the most challenging and elusive, concepts they have encountered. Recently, for example, a RAC long-range study titled Project CALCHAS concluded that the measurement of military effectiveness was one of the most important problems facing the Army over the next 20 years. The systems analysts in this study group found serious difficulties in the verification and credibility of current measures of combat effectiveness. Their findings would have been equally applicable to current measures of logistic effectiveness.

To illustrate some shortcomings that are associated with many of our current measures of logistic effectiveness, let us consider several specific examples. The readiness of battalion-size units to undertake combat operations from a repair-parts standpoint currently is measured by the percentage of items stocked at unit level that have no stock on hand at a given point in time—that is, the percentage of items that are in zero balance. This measure is a poor indicator of a unit's repair part posture because it fails to consider whether the items stocked are the ones the unit really needs, whether requests were received when the items were out of stock, and whether the amount of stock on hand is large or small compared with the amount authorized to be on hand. Just as important, it is a negative type of measure that discourages desirable logistic practices. In fact, the zero balance measure has placed such a premium on keeping stock on hand that it has prompted some units to refrain from issuing stock and others to postpone vehicle maintenance. Alternative measures that overcome these deficiencies are available, but to date little progress has been made in adopting them.

Other measures of logistic posture that are sorely in need of overhaul are concerned with equipment readiness. The multiple measures of vehicle readiness that are currently being employed constitute a crazy quilt of indicators that are difficult to interpret. We measure readiness in terms of deadline rates, equipment serviceability criteria (ESC), preparation for overseas movement (POM) criteria, command maintenance management inspection (CMMI) criteria, and overhaul standards. Many of these measures are inconsistent and some are contradictory. Some, such as equipment serviceability criteria scores, have proved to be unreliable predictors of subsequent maintenance experience. In spite of these deficiencies, however, systems analysts currently are devoting very little effort to resolving these discrepancies or to developing more meaningful measures of equipment readiness.

The effectiveness measures that require improvement predominantly logistic posture measures are not associated with the retail portion of the supply system. A comparable need exists at the wholesale level. In fact, analysts at the national level sometimes appear preoccupied with measuring performance in terms of such statistics as ton-miles of cargo transported per unit time. We can move tons of materiel, however, without appreciably enhancing our logistic posture. As our experience with Red Ball requisitioning has repeatedly demonstrated, we frequently encounter difficulty in satisfying the theater's needs of items that weigh only a few ounces and cost only a few dollars. Or is it that these light-weight items have already been shipped to the theater in sufficient quantities and are stored somewhere in Vietnam but simply can't be located? Or is it that current supply procedures are so complex and error-prone that it is extremely difficult to estimate repair part requirements accurately?

In the coming months, as AMC extends its ownership of selected secondary items to the oversea-depot level under the OASIS program, AMC analysts will have a better opportunity to answer questions such as these. Implicit with this opportunity, however, is a twofold requirement, first, the specific performance measures that will be used in managing the OASIS items must be identified and, second, the manner in which these performance measures will be applied to achieve monitorship and control must be determined.

Undoubtedly, AMC managers have already given considerable thought to each of these requirements; hopefully, however, several of the following observations will also prove helpful. With regard to the first of these requirements, a whole host of performance measures will be needed to gain effective management control over the OASIS items. In fact, these performance measures should cover every phase of logistic operations, because over the years we've observed that logistic procedures and discipline have a tendency to break down in unusual and frequently unexpected ways. Among the many performance measures that should be considered in managing the OASIS items are those that indicate the compatibility of depot due-in-records with NICP due-out records, the extent to which depot asset balance figures agree with the quantities of stock physically present in depot storage locations, the accuracy with which the NICPs are able to forecast the demands for OASIS items, actual versus estimated order and ship times between CONUS and the oversea depots, and the ability of AMC personnel to update the OASIS list by adding items that meet specified criteria and deleting those that do not.

Taking note of how the performance measures should be applied, we've observed that higher headquarters, such as USAREUR and AMC, frequently monitor the operations of their subordinate elements by examining feeder reports that are submitted at periodic intervals by the units being reviewed. In many cases, however, the information in these reports is so inaccurate, inconsistent, or untimely that it is of little value in identifying potential problems before they develop into full-blown crises. Instead of relying principally on periodic reports provided by subordinate units, in many cases it appears both feasible and desirable for systems analysts at higher headquarters to obtain and analyze the information that is necessary for them to achieve continuous monitorship over the operations of the units within their command.

With reference to the OASIS program, for example, systems analysts from Headquarters AMC could sample on a daily basis the various kinds of supply, maintenance, and transportation data that are generated during the normal course of depot-level operations within Vietnam and, whenever appropriate, could compare these data with corresponding NICP operating information. Such comparisons would allow the continuous monitorship of oversea depot due-ins with NICP due-outs, of order and ship time between the oversea depots and CONUS, and of NICP accuracy in forecasting the demands placed on the oversea depots. In addition, adopting the concept of obtaining continuous monitorship by AMC personnel would allow the accuracy of depot asset information of the kind reported under AR 711-80 to be assessed more readily as well as the performance of the individual NICPs in meeting the objectives of the OASIS program.

The specific example just cited pertained to a program of interest to AMC. The concept of applying performance measures in a manner that will provide continuous monitorship and control, however, is pertinent to many additional types of logistic operations. It could be applied to other activities under the purview of AMC or to logistic operations across all echelons of commands, such as USAREUR or USARPAC.

We believe, therefore, that systems analysts should devote much more fundamental research to identifying logistic effectiveness measures that are more meaningful than those in common use today, and to designing systems of management controls that will allow the performance of the overall system or of selected programs to be monitored on a continuous basis and that will facilitate the initiation of timely corrective action whenever performance drops to substandard levels. If we are successful in improving our measures of logistic effectiveness and our ability to monitor logistic activities, we can expect to achieve large-scale, permanent improvements in logistic operations.

By way of summary I'd like to add a few comments on the observations we've made here today I need hardly tell you that research in logistics problems is often frustrating, for progress in improving logistic operations is elusive and often painfully slow. But it is also challenging, and can even be fascinating, for the potential, and the prospects, of effecting improvements are great.

Our relationship with AMC has been a satisfying one. This has resulted in part from the close, almost day-to-day liaison and communication between our analysts and the people with the problems and from the degree of interest at the highest levels in your command. From our observations, however, it is obvious that we think there is room for improvement, particularly involving the content of the research program. We have stressed particularly our concern over what we consider a disproportionate preoccupation with short-range problems, which favors improvement of the existing system at the expense of examining more basic problems and preparing for the future. This is not to say that you, as operators of the Army's logistics system, should not be concerned with improving the performance of the existing system. We believe, however, that it should be more concerned with future systems. If the Army is to avoid the risks involved in treating merely the symptoms of more basic problems and in searching for suboptimal solutions that merely patch up existing systems, it must, we think, do two things. First, it must welcome uninhibited questioning and challenging of its prevailing concepts, organizations, policies, and procedures. Second, it must support the search for better methods of measuring logistic performance. Without the latter it simply never can test the efficacy of a system and compare alternative concepts.

These two objectives, in turn, unavoidably involve long-range research, since they require the examination and evaluation of new concepts through the use of new techniques such as simulation.

We have appreciated having this opportunity to address this group. In the spirit of your invitation, we have tried to make a candid appraisal of our work for AMC and our relationship to your command, at the same time searching our own souls. The intent has been to find ways of improving our usefulness to you, always bearing in mind the sponsor's point of view.

OPERATIONS RESEARCH IN AMC–PAST AND FUTURE

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My invitation to address this symposium suggested that I might present a frank critique of AMC's past performance in systems analysis, or I could discuss what I thought AMC had been doing wrong and how they might improve. I thought a lot about those questions and the unique opportunity they presented. After all, while I was a practicing analyst, first with the Ordnance Corps and then in AMC, I ran into more than my share of management decisions which I considered to be quite poor. I also ran into far too many unfair judgments of my own superb efforts. And now I was being offered the chance to return and, if I wished, to really unload. I could, for example, discuss some of your very *recent* mistakes, or, if I chose, recall instances of your *past* mistakes - or I could even use this time to explain why many of you should have listened to me years ago. But please let me set you at your ease, I quickly rejected those rash impulses. And I did so, not only for the obvious reasons, but also because I have become more and more concerned about a trend in the Army which has become so unfair as to be unhealthy - and I, for one, do not intend to contribute to that trend.

I am talking about my increasing concern with the recurring self-deprecating dialogue which has become the vogue for far too many elements in the Army. To engage in self-critical dialogues is always, of course, desirable. It becomes unhealthy, however, when such dialogues continue to present an inaccurate image of the Army, or in this case, of the Army's study effort. It is clear that such dialogues have a natural tendency to become overcommitted to self-criticism and, unfortunately, when that happens, it does so at the expense of an honest search for solutions to the problems which face the Army. I believe we have tended to beat ourselves over the head much too much. I know it is unwarranted, and I am convinced it must stop.

And so, while a symposium of this nature, which asks the question "How do we improve our research?", is bound to take on a somewhat negative tone, especially in light of the trend I have just discussed, I would like to start out this morning on just the opposite note.

Let us remember how AMC was established. After all, AMC was initially the coalition of the Army's old Technical Services. By their very nature, the Technical Services were committed to the support and use of research, and operations research was no exception.

Let us not forget that the Ordnance Corps started to develop and perform systems analysis about 23 years ago, several years before the establishment of ORO (now RAC) and long before this profession of ours was embraced by the Office of the Secretary of Defense. I checked the other day and found that formal systems analysis began in the Army just about the time Alain Enthoven became a high school sophomore. Personally, I find such memorabilia a great aid to perspective.

Even a cursory review of the Army's history in Operations Research (OR), since 1946, will reveal that the Army pioneered in the development of many methods, models, and inputs required for good systems analysis. For example, the Ordnance Corps pioneered in the conduct of enemy threat analyses, yes, gentlemen, in enemy threat analyses. By no stretch of the imagination was it the Ordnance Corps' responsibility to conduct such analyses. Yet, it was required since no one else was doing it, and so the systems analysts in the Ordnance Corps did the job.

Above all, let us recognize that these pioneering efforts went on to produce many excellent studies. Studies which are still classics in the field of weapon systems analysis and which still act as a standard for many of today's efforts.

We must not forget that two of the Army's major OR organizations, the Weapons Systems Laboratory at Aberdeen and ORO (RAC), each have more than 20 years of continuous experience in this field. I submit that not only is this a heritage you can be proud of, but more importantly it means you possess a solid foundation on which to build further progress. So, let us continue to be self-critical but never to the extent that we overlook our long heritage of excellent work and the excellent basis it provides for the future.

In any discussion of AMC's long standing and well-established position in OR, I am always quick to point out certain of its aspects which make it both unique and enviable. Its uniqueness results because for years you have been very close to the systems you have been studying. Historically, you have been in the business of generating the many and varied input data required for a full understanding of the models you were using. As developers of the various inputs, and as nursemaids of the equipment, you have literally lived with the problem. You know it better than any outsider can and this is a great advantage. There is perhaps a danger of overcommitment here, particularly when closeness to the systems, as characterized by localized OR groups, may develop harmful parochialisms.

I cannot emphasize enough that the ability to obtain, develop, and work with the basic inputs required for your studies, and to carry out experiments suggested by your analyses, represents an asset of untold worth. You all know that one of the central problems of military operations research continues to be the paucity of good input data, and anyone who has it, or who can get it and understand it, automatically has a tremendous advantage. If you doubt this, if you cannot understand how valuable that asset really is, then just consider for a moment how many analysts from outside groups come to you for data. Ask yourself how many of your contractors, before they even begin to help with your problems, must first come to you for data and for their general education.

The Army, through its years of experience in the Weapons Systems Laboratory (now AMCSA), through its years of experience in ORO (now RAC), and through its many activities elsewhere, has developed, to my mind, a truly complete capability to conduct military operations research and systems analyses. Complete in the sense that it is based upon the development and understanding of the fundamental input data which are required; complete in the sense that it can then use that understanding to develop much more meaningful models and other analytical tools. I repeat that this complete capability places you in an enviable position, a position which you must fight to maintain at all times. Having attained this type of capability carries with it the responsibility to maintain it. You dare not allow it to be dissipated. When poor or missing data are surfaced in your studies, you must ensure that adequate experiments are conducted to help develop those data and to fill the gaps. In this way, you will not only preserve your unique capability, but you will also be able to continue your support of the many other organizations who also require those data. By any measure, you in the AMC have built a solid foundation which gives you a let up on many others working in the same field. You must now meet your responsibility to use that foundation for further progress.

Having suggested that we needn't feel too concerned about AMC's fundamental position in the OR community, I would now like to suggest that perhaps that position has not been fully exploited. I would like to suggest that perhaps you have not been using your foundation as well as you could in your desire to progress. I believe that you have not done so for three reasons.

First, I believe it is due to a slowness in adapting to new research requirements. Second, I believe it is due to a somewhat inefficient utilization of your research talent and inefficiencies in the training of new talent. And, lastly, it is due, I believe, to too little initiative in working with and responding to the higher echelons in our defense establishment. I will discuss each of these in turn.

I will begin with a discussion of new requirements. As I have already stated, AMC pioneered in OR and as such concentrated on the first order of business - weapons selection and requirements. While it was recognized even then that this was only part of the "cradle-to-grave" responsibility that the technical services had for equipment, the tendency was to concentrate on the "cradle" portion of the life cycle. Of course, this was not unusual since the Army was just beginning to feel its way and it made good sense to begin at the beginning. Today, however, the situation has changed considerably as you are well aware. The system requirements portion, an early portion of the lifetime cycle, is no longer the responsibility of AMC. It is now CDC's primary function.

The fact that CDC has that responsibility has been only gradually and very grudgingly accepted in certain quarters within AMC. Unfortunately, there has been a reluctance by some of you in AMC to release your hold on those kinds of analyses. Some of you argued, and still argue, that since AMC was obviously the most experienced in the conduct of requirements studies, the Army should have logically assigned that responsibility to AMC. These critics do not believe that many of the advantages envisioned by the creators of the Army reorganization warranted this intrusion upon their long held position in the field. And while I might personally agree that the Army reorganization may have concerned itself too much with the redefinition and redistribution of responsibilities, and not enough with the redistribution of resources necessary to fulfill those responsibilities, I nevertheless believe we must stop worrying about what happened some 6 years ago and begin to work within the new organizational setup. Let us stop fighting it. Not only does a reluctance to accept the reorganization hamper the Army in its efforts to improve, but this preoccupation with what might have been or what should have been tends to inhibit your excellent resources from doing the AMC job. And that is what should concern us all today - the AMC job. I say to all of you, and especially to those who helped pioneer the "cradle" portion of the life cycle, that it is time to look ahead at the many problems in the much longer time span which constitutes the many later phases in the life cycle. AMC's work in operations research must now address the later phases in the life cycle of military systems. You must begin to look seriously at such problems as maintainability, reliability, repairability, replacement, and logistics.

These problems, while obvious, are also difficult. For example, let us examine some of their implications. The appropriate application of OR to these relatively new areas is going to require large masses of new input data. The preservation of your complete capability will, in addition to the establishment of appropriate measures and analytical models, require the development of many basic inputs to help measure and understand these new entities. Is it perhaps too soon to suggest the eventual establishment of an AMCEC or an AMC Experimental Center - a counterpart to CDCEC? - a center which is much more than a proving ground, a place where data relating to maintainability, reliability, and repairability will be developed from actual usage in realistic and instrumented field exercises. Perhaps this concept can be tried first by working together with CDCEC. Of course, much of the required data can be developed from first principles, but the establishment of an AMSEC is something worth thinking about. Perhaps some of you are thinking that this suggestion is way out. I counter by stating that such thinking stimulates action - and immediate action to pioneer and proceed into these new areas is what AMC *must* do.

Having suggested that you must attack the later phases of the life cycle, I want to make it quite clear that I am not saying that combat effectiveness as it relates to system requirements is no longer an AMC concern. As long as weapons development remains AMC's business, the establishment of requirements will continue to be of interest to AMC. I think, however, it must now be put into proper perspective as part of the much broader concern which I like to refer to as 'life time effectiveness' - an important aspect of what some have called 'life cycle management'. This is an important aspect of the general shift in the scope of analysis that I believe must take place in the Army; and it should be viewed most seriously by you in AMC. I know that there are people in the audience, General Bunker and others, who have been preaching this word. I merely wish to emphasize the importance of getting on with the job.

I would like to suggest also that you must emphasize the need to employ the whole system approach. This is not really a new requirement, but we have seen evidence that more thought should be given to its application. In considering equipment, for example, you must continue to ask such questions as "What does this weapon or this kind of equipment contribute to the effectiveness of the entire organization?" We can no longer assume that all we have to do is to improve specific items of equipment and then let someone else make the necessary slight adjustments in the related organization. Each prospective change must be related to a change in the "output" of the organization as a whole. For example, there are obvious tradeoffs in examining the weapons and equipment that compromise a combat force and the service support capability which must be tailored to that force. These considerations must become part of your overall effort.

Another requirement, which should receive additional emphasis, is the need to strike a better balance between cost and effectiveness in the analyses being done for the decision-makers. While I have already detected a significant increase in the emphasis you have been giving to the cost side of your analyses, I wish only to ensure that it not be interpreted merely as a more accurate prediction of the price tags. As you know, there is a big difference between cost and price. Actually, I prefer to use the more cumbersome term "resource expenditures" to emphasize the more fundamental and choice-provoking sense of cost as it is understood today. An indication of the growing appreciation of both the significance and complexity of the cost side of analysis has been the use of such terms as 'lifetime costs' and 'cost modeling' to describe what is being done. To work effectively in this area, you must bring together your experts in developing the price tag with those who are familiar with the development of cost models which relate accurately to the effectiveness or capabilities of the systems. Only in this way can effective 'cost modeling' be conducted.

Today, cost models are too often found in the hands of the 'pricing' experts, an unfortunate overcompensation in an attempt to correct the relative neglect of cost in the very near past. 'Cost modeling' must involve a strong appreciation of the total system and its effectiveness in order to be realistic.

I have discussed some requirements and new emphases which I think you should consider for the future. I know that you have already addressed some of these concepts, but I thought it worth repeating with a slightly different twist. Before leaving this subject, I would like to single out again the urgent requirement that you begin to study and apply your OR talents to those problems involved in the later phases of the life cycle. These areas are definitely within your responsibility and must not be neglected.

The second major topic I would like to discuss today is the use of your available operations research talent and the importance of training new analysts. As I have said, I know that you have a good cadre of experienced analysts. That group must be supplemented, however, by new analysts who, after sufficient training, will carry on the work of AMC. If I had to single out one reason why AMC and other elements of the Army have demonstrated weaknesses in their study efforts, I would say it was simply because there are not enough trained professionals to meet the tremendous demand that has been generated in the last 5 to 10 years. Whatever else might be said about Systems Analysis in OSD, you must agree that they deserve the credit for having popularized our profession more than any other single element in this country. Nor is there any question that this increase in popularity has created an equally great demand for professional services which is way out of balance with our available supply. It is an imbalance, incidentally, which exists in almost every component of the defense establishement. The problem for AMC, as well as for others, is how to best use its available resources and how to go about training the additional resources that are needed to meet both current and future demands. To do this realistically, I believe that AMC will have to take a hard look at some of its current plans for the organization and management of its OR resources. The natural tendency, considering the very great demand, is to *organize* in an attempt to solve the problem. And, unfortunately, to *organize* usually involves the establishment of many small groups throughout the breadth and length of the major organization. While I am convinced that this tendency is a natural one - since almost everyone tries it - I believe it is wrong and self-defeating to do so today. Based upon my observations, I note that the establishment of a large number of small organizations usually results in their staffing - not because good talents are available to fill the approved slots - but only because the organization and the slots exist. And once this phenomenon begins, the non-professionals - the pretenders - soon begin to take over - and that too, is not surprising since there are so many of them. Almost immediately, they assume the role of administrators, not as operating analysts; they have to do so since they are not equipped to do otherwise. Eventually, such organizations are characterized by layer-upon-layer of administrators, or as they prefer to call themselves, 'monitors or reviewers.' This invariably becomes a classical example of the blind leading the blind and results in a repeat of the cycle. The cycle is repeated since it is now necessary to solve the inevitable problems which result, and to do so we then hear cries for more organizations and more manager/monitors.

I seriously recommend to AMC, as I have to others, that today some form of centralization is going to be necessary. I recognize the dispersed nature of your commands, but for the time being, you must find a way to concentrate your available talent into a much smaller number of organizations. You must do so, at least until those organizations begin to develop the necessary talent to staff the additional offices you would like to establish to meet your needs. In our office, we have seen repeated instances of organizations, with limited resources, who by the mere concentration of their resources, have successfully managed to produce excellent studies. It is only when organizations have allocated their study requirements among many small organizations, each having limited talent, do we begin to receive a spate of studies which invariably require redoing - primarily because they are poor technically. But also because localized groups tend to develop some very unhealthy parochialisms.

By some form of centralization, you 1) will be concentrating your best talent on important issues, 2) will be maintaining a higher level of objectivity, and 3) will be taking a very major step toward solving the related problem of training new analysts. In this latter regard, I submit that the effective training of new analysts must be undertaken by seasoned professionals. It takes much more than one or two degrees in mathematics, physics, or even operations research to make a good analyst. Our experience continues to show that regardless of academic background and attainments there is about a .5 percent probability that an individual will become an effective analyst. But even for the 50 percent who will, it is going to take a fairly long apprenticeship of actually doing OR studies. Centralization of your current talent will give you the organizations which not only can manage and conduct large segments of your OR effort, but which can also act as the necessary 'universities' in which newcomers to the field within the AMC can learn the trade. Apprenticeship of the kind I am talking about cannot be met by dispersing new employees among many organizations each having a minimum of talent. Let's face it, today you cannot recruit or train enough experienced analysts to maintain all of the research, managerial, review, and training positions that a large number of dispersed groups will require. You will note that I include managers and reviewers as a part of your general problem. I do so because effective management is usually characterized by a relatively *small* number of *competent* and *experienced* managers and reviewers. And if, as I believe, you must draw these personnel from the group of *experienced doers,* (yes, I believe 'reviewers' should have been 'doers'), then automatically you must organize into a relatively small number of organizations since there are simply not enough experienced personnel to go around.

All of these thoughts, suggest to me, the desirability of concentrating your experienced analysts in a relatively small number of groups. It was for these reasons that we were favorably impressed with the recent establishment of AMSSA. In addition to the objective conduct of your important analyses, I would certainly use AMSSA as one of your major training grounds for developing the seasoned analysts, managers, and reviewers which AMC will require in the future. I would like to suggest that, in considering your need for training centers, you not overlook the capabilities available in RAC. RAC's many years of experience, which I referred to earlier, must not be wasted. The excellent resources at RAC can help with your study effort and also to train your future analysts.

Before I leave this question of training, I would like to single out the military and discuss how we might improve the training of officers in OR. I have not had time to fully research how officers with academic training in OR are utilized within AMC, however, I have watched their utilization in other parts of the Army and find it to be poor. The training of officers in OR must include the opportunity for applying the material that they have been taught in school; and that experience should be gained before they move on to review or management positions. I believe it is a mistake, both from the standpoint of the individual and from that of the Army, to place an officer, freshly educated in OR, directly into a staff slot requiring the review of studies. Yet this happens every day within the Pentagon. Such assignments do not help the officer to mature as an analyst, and they are wasteful in a more fundamental sense. We know that at some later point in his career the young officer will undoubtedly return to the Pentagon as a top manager responsible for some fairly important areas. Yet if we continue the aforementioned practices, that individual would have had only 1 year of research experience—and that in school. As you can surmise, when he returns to the Pentagon as a lieutenant colonel, colonel, or general, he will then require junior managers or reviewers to help him, and unless we do something about the system, those officers, like himself years before, will have had only 1 year of academic training. This is certainly not the way to train the military, or anyone else for that matter, in this field. Apparently, the military establishment is willing to dedicate 3 to 4 years of an officer's career toward attaining experience in OR. Accepting that, I would recommend that after his year or two of formal education, the officer be immediately assigned to one of the operating organizations. Assign him to AMSSA, RAC, SRI, or others, and let him learn the business while on the job. Sending him to those organizations to act as a liaison with the military community is not what I am talking about; let us send him to those organizations to work on specific problems assigned to the various operational groups within those organizations.

I wish to discuss one more subject this morning. I believe that AMC can progress better in OR by using more initiative and imagination in responding to higher echelons. I mention this because of another trend which has been in evidence in the Army. Too many individuals who just meet and begin to deal with the OSD system of decision-making, quickly arrive at the conclusion that the way to really 'beat' the OSD system is to "sell" their product or to cater to some OSD analyst. And incidentally, most of these beginners invariably conclude that all of their predecessors were notoriously poor salesmen, and that they are the sales experts the Army has been waiting for. Now, there is no denying that in some sense the Army is trying to sell its products. Unfortunately, we are developing a distorted view of good salesmanship. Without going into the reasons (some of which I have already mentioned in other comments), I find too much emphasis on the too quick and arbitrary establishment of Army positions and on an equally arbitrary set of 'back-of-the-envelope' studies which are prepared expressly to "sell" the poorly conceived positions. These feeble efforts are then presented to OSD with the bravado and confidence of the topmost salesmen. I can say to you here today, on the basis of careful observation, that this type of sales approach is almost certain to fail. Let's examine the situation. After all, who are these analysts in OSD? They are a group of people who, for various reasons, have been employed in OSD and, thereby, have been given considerable authority. But they also possess other characteristics. They display the same shortages and lack of good professional talent that you find in AMC and in other elements of the defense establishment - perhaps even more. Once you recognize that fact, you begin to understand how chancy poor analyses or the mere catering to these influential personnel can really be. Oh, how many times I have seen attempts to cater, or to pass poor products, fail miserably, and they fail for a variety of reasons. First, they fail because the elements who have been catered to do not turn out to be the elements who make the final decision–a most rude awakening. The caterers often find that they have been catering to the wrong gang. Another fairly obvious reason is that many of these so-called influential elements turn over very rapidly, and you suddenly find that those who seemed to buy a particular pitch are no longer there: and, incidentally, their presumed acceptance of certain views are almost never binding on the new gang. But chiefly, these sales pitches fail because the quick back-of-the-envelope attempt to justify preconceived conclusions will almost surely be surfaced by some experienced analyst somewhere along the line. Now, I am not against your maintaining a continuing dialogue with pertinent elements at all higher echelons. In fact, I wish to go on record that I encourage it. But, please don't degrade that dialogue. Don't degrade it by assuming that you can somehow outwit, outmaneuver, or circumvent the higher echelons. That approach will work only sometimes. Use that dialogue instead to inform yourself about what these people need and also to understand their guidance. But most importantly, and I want to stress this, if you believe that they are looking at the wrong problem, asking the wrong question, or that their guidance is wrong, bring it to their attention and try to get them to change. But even if you feel so constrained that you must do what you are told and not question higher authority, you should, in addition, conduct those analyses which reflect what you believe to be correct. As I mentioned earlier, you are in a much better position than most other people to know what is the right kind of research, and you have the better capability to produce the evidence which can prove that you are right. I guess what I'm saying is that you should, of course, worry about the Dr. Enthovens and the Dr. Paynes, but don't do so to the exclusion of what you believe to be right. Determine for yourself what you consider to be the correct objectives of the assigned task. Do the best possible study you know how to do and make those recommendations which derive from those analyses. Wherever possible, work within your guidance, but if you think it necessary, do more. In the last analysis, that is the only effective way to sell anyone's product.

Before leaving this subject, let me encourage you to include education as a central part of your dialogue with higher echelons. Let me illustrate. One of the more frustrating parts of my job is that, like you, I must often deal with some who know little about the subject under consideration. The other day, for example, my secretary arranged an important appointment. A Mr. "X", in OSD, had called asking for an appointment to discuss certain weapon systems. He arrived promptly at the appointed hour. We went through the usual amenities, and I asked him when he had arrived in OSD. He was a very young man who had just graduated summa cum laude with a bachelor's degree in a nontechnical area from one of the leading universities in this country. I then asked him what he had come to see me about, and he started by telling me that for the previous 2 weeks he had been reading some of the Army's studies of a certain class of weapon systems. He went on to tell me that he found them very disappointing - incorrect, in fact. I asked him what studies he had read, and when he told me, I singled one out and asked him to tell me what he found in that specific study. He pulled out his notes and quickly rattled off five deficiencies. In each and every case, he had completely misunderstood what had been done. I pointed out some of his errors and suggested he reread the reports. Yet, I am sure that his erroneous impressions had already been conveyed to his superiors.

Our only hope in such situations is to attempt to teach the individual concerned. It would be wrong to ignore such individuals. In fact, that man represents a real ray of hope. Remember, my visitor had read the reports - and had, thereby, displayed a willingness to learn. Many of you know I have been trying to educate by arranging for various get-togethers between OSD and some of you. But, that is not enough. In all of your dialogues you should keep in mind that any time spent in education may provide a greater pay-off in the long run. I know that by so doing you will certainly help me; I believe that eventually it will help us all.

In conclusion, I would like to repeat that AMC has an effective and sound organization upon which to base its further progress in the application of operations research. I believe there are some new directions which you must take, especially in the later phases of the life cycle. You must also recognize that many of the problems you face today result from a lack of good professional assets, and that somehow you must centralize to make the most efficient use of those limited assets. Having done so, those organizations must then act as the training grounds, the 'universities', in which to train the next generations of analysts. Lastly, rethink your relationships with the higher echelons. Understand them better, continue your dialogues, but never forget that you are professionals and that as such you have a responsibility to question and to do the best professional job you know how to do. There will always be many pressures on you - from on high. Above all, maintain your objectivity.

A TIME DEPENDENT ARTILLERY EVALUATION MODEL

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Before describing the Time Dependent Artillery Evaluation Model, I shall briefly describe the problem to be solved and a few of the weak points of previous models that led to the development of an evaluation model that considers the time dependency of events.

The basic problem is to choose among many candidate artillery systems those which either add to existing capabilities or significantly reduce the cost of maintaining an existing level of effectiveness.

To illustrate the problem, consider a present family of artillery consisting of two cannon types, A and B. Two missile systems are being examined as alternative candidates to be included as part of a future family of artillery. Missile X can be thought of as a small, accurate system and missile Y is a larger more inaccurate missile system.

The pertinent questions to be answered are:

- Will a missile system reduce the cost of attacking a threat vis-a-vis the present family? (Constant Effectiveness Problem)

- For a given cost, can an added missile system increase the number of threats that can be attacked? (Constant Cost Problem)

- If a missile system is desirable from one or the other of these standpoints, which missile should be built?

The basic approach that had been used to attack this problem is shown schematically in Chart 1.

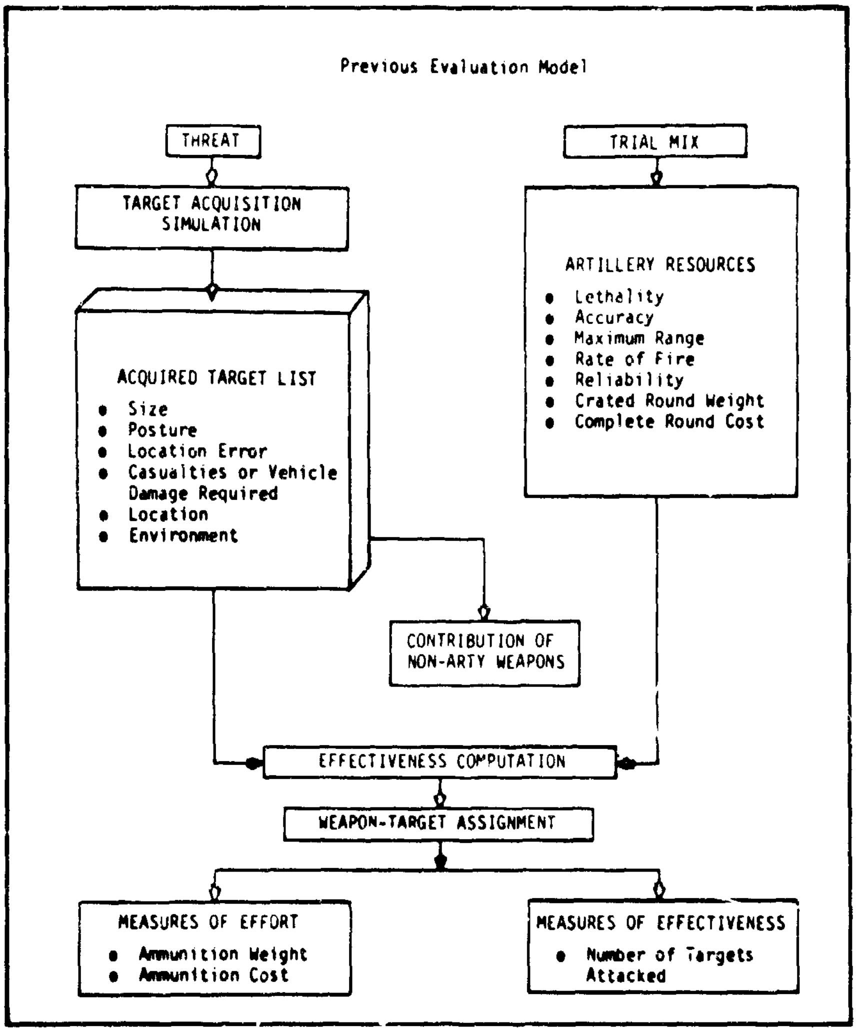

Chart 1

The left branch reflects the firepower requirements imposed on the artillery resources of the right branch. The Artillery resources are represented by a mix or family of weapons selected from existing weapons and one or more candidate systems.

The requirements and resources are combined in the effectiveness computation. Number of rounds and associated ammunition weight and cost are determined for each of the weapons in the trial mix to attack each of the targets in the threat.

Each target is then allocated to the weapon in the trial mix which can attack it with minimum ammunition weight or cost, whichever criterion is chosen. A summary is given of total weight and cost of ammunition expended by the mix and the number of missions assigned each weapon of the mix.

A weapon designed to attack specific target types is given an inherent advantage in the model compared to weapons that do a fair job against a wide variety of targets.

The model is limited to making relative comparisons. What is needed can be determined, but not how much.

Allocation based on minimum cost is not exact because of the relationship between unit cost and number used and those produced. Since the analysis is basically one of comparative cost for equal effectiveness, the worth of additional capability cannot be measured.

The last problem area shown, however, is the greatest problem area. In our example, it was noted that missile Y, the large missile, was more attractive than the smaller one. In a real combat situation, however, many demands are placed on artillery systems in short periods of time. It may be that the best weapon cannot be matched with appropriate targets. Suboptional allocations then result. The apparent difference in munitions required when comparing missile X and missile Y might be wiped out by these suboptional assignments. It is even possible that the smaller missile could be more desirable under these conditions.

This phenomenon was labeled "surge" by the Department of Defense. It was a new concept to us and required the formulation of a workable definition so that the model could be extended to evaluate it in all its ramifications.

The definition that was adopted for this term which permitted quantitative treatment is an artillery force that is in a surge situation when the total number of fire missions presented to the force over a period of time exceeds the number of fire missions the force can perform. With this definition to work from, an extension of the model to include the dimension of time was undertaken.

Analysis of results consists of a comparison of weight and cost for different mixes to attack the targets in the threat. Comparisons of numbers of targets attacked by the weapon in the mixes can be made. Care must be taken that all mixes whose weights and costs are being compared are capable of attacking identical sets of targets else both cost and effectiveness vary simultaneously and the results become indeterminant.

Chart 2 shows the results of such an allocation procedure with our sample problem.

PERFORMANCE OF ALTERNATIVE WEAPONS ON THE PORTION OF THE THREAT THAT THE PRESENT FAMILY CAN ATTACK				
	MINIMUM WEIGHT ALLOCATION		MINIMUM COST ALLOCATION	
FAMILY	TOTAL CRATED WEIGHT (KMT)	TOTAL AMMO COST (KILO $)	TOTAL CRATED WEIGHT (KMT)	TOTAL AMMO COST (KILO $)
PRESENT	100	300	100	300
PRESENT + MSL X	60	360	95	300
PRESENT + MSL Y	40	280	45	270

Chart 2

When the allocation is based on minimum weight, the addition of missile X to the present family reduces the total weight needed to attack the targets. The dollar cost is increased. Howev. r, if instead of missile X, missile Y were included in the present family, a greater savings in weight compared to missile X would result and cost would be reduced relative to the present family. If minimum weight is the desired criterion, the missiles significantly reduc the weight required to maintain present capability; of the two missiles, missile Y is more desirable.

A similar conclusion is reached when minimum cost is the basis f r the allocations.

Chart 3 was the basic tool used in the analyses of the studies shown on this viewgraph.

STUDIES EMPLOYING OLDER MODEL

JAN 63	BRL	A COST EFFECTIVENESS ANALYSIS OF TACTICAL NUCLEAR WEAPONS
APR 63	SEAMAN BOARD	FIRE SUPPORT REQUIREMENTS STUDY
APR 64	BRL	COST EFFECTIVENESS ANALYSIS OF MULTIPLE ARTILLERY ROCKET SYSTEMS
SEP 66	BRL	REOPTIMIZATION OF A MULTIPLE ARTILLERY ROCKET SYSTEM - MARS II
JUL 67	CDC	PRELIMINARY ANALYSIS OF THE OPTIMUM MIX OF ARTILLERY UNITS 1971-75

Chart 3

Experience with this model led to increased appreciation of its weaknesses. Some of its problem areas are:

- Leads to specialized systems
- Limited to relative comparisons
- Restriction to parametric analysis of cost-quantity relationship
- Poor measurement of increased capability
- Suborbital solutions not analyzed.

The resulting model is shown in its entirety in Chart 4. The component parts are isolated in Charts 5 and 6.

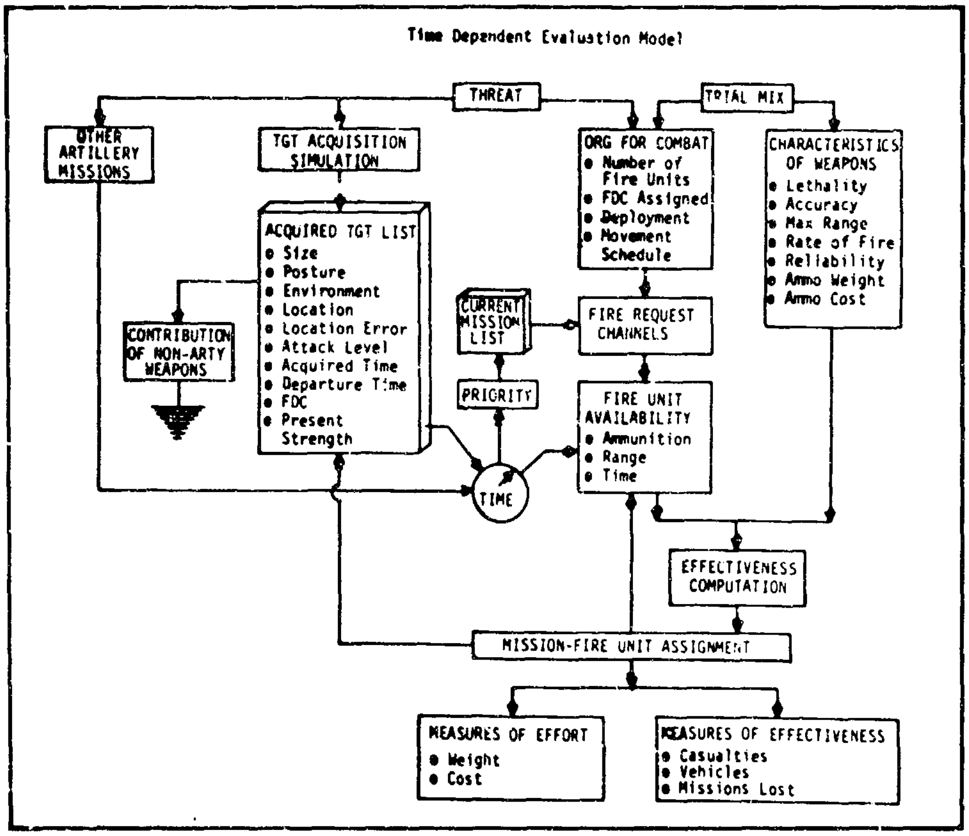

Chart 4

Chart 5 shows the treatment of the firepower requirements. The crosshatched portion of the schematic show the parameters that were considered in the older model. The dashed boxes show relationships to other portions of the model.

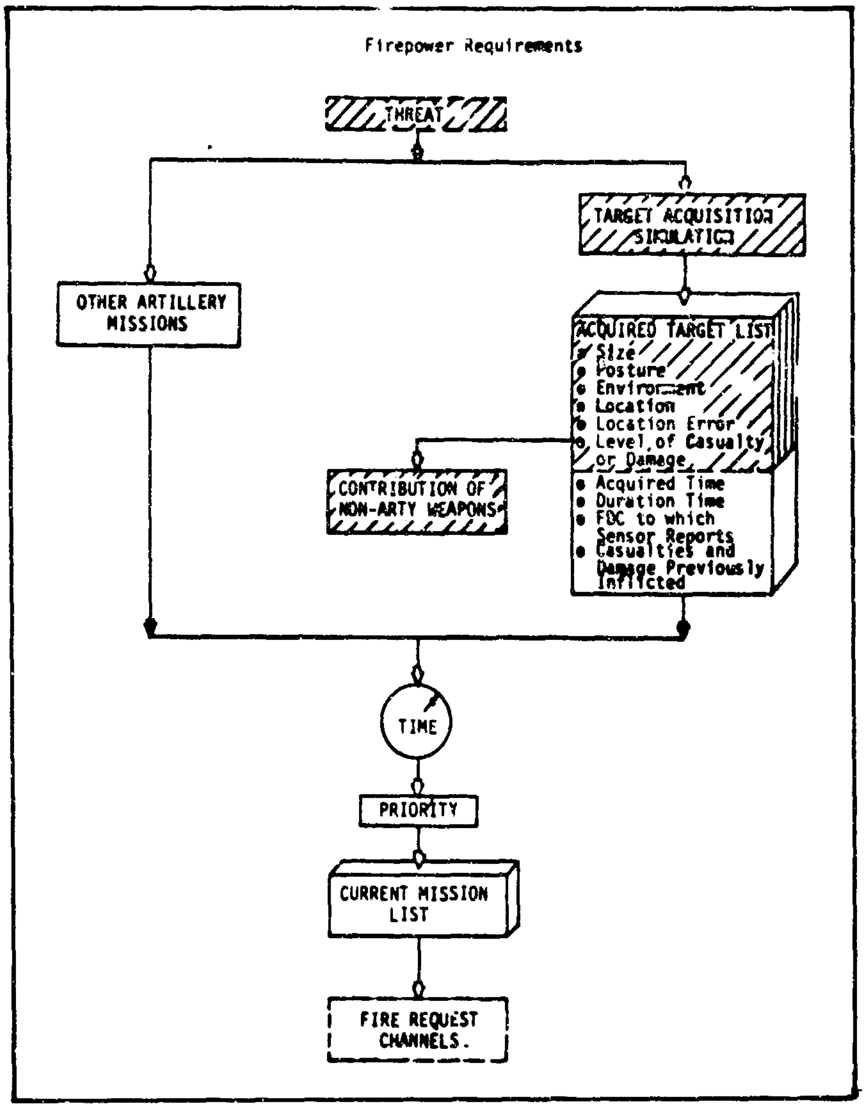

Chart 5

More information is extracted from the threat data Mr. Reid provides. The missions are separated into two categories: other missions such as smoke, illumination, H & I, or final protective fires and acquired targets. Both types are described in terms of similar parameters, the primary difference being that other missions are computed from frequency consideration while acquired targets result from unit deployments.

The additional information that must be provided for each mission consists of:

- Arrival time at the fire direction center
- Estimated duration time

. The organizational level of the FDC responsible for the mission

. The accumulated amount of damage done the target on prior missions. Since the same enemy unit might be acquired several times during a day, some provision must be made to accumulate damage. Units having accumulated damage above some specified amount are withdrawn and all subsequent missions corresponding to acquisitions of these units are deleted.

All artillery missions occurring at a particular time are selected. They are next sorted according to the priority with which they would be considered by artillery commanders. The higher priority targets will be processed first so that their demands on artillery resources can be met before those of lower priority missions. The resultant current mission list constitutes the total firepower demands placed on the artillery at that time.

Chart 6 is a schematic of the artillery resources, the effectiveness computation, and the allocation subroutines of the model. The dashed boxes and shaded boxes have the same connotation as before.

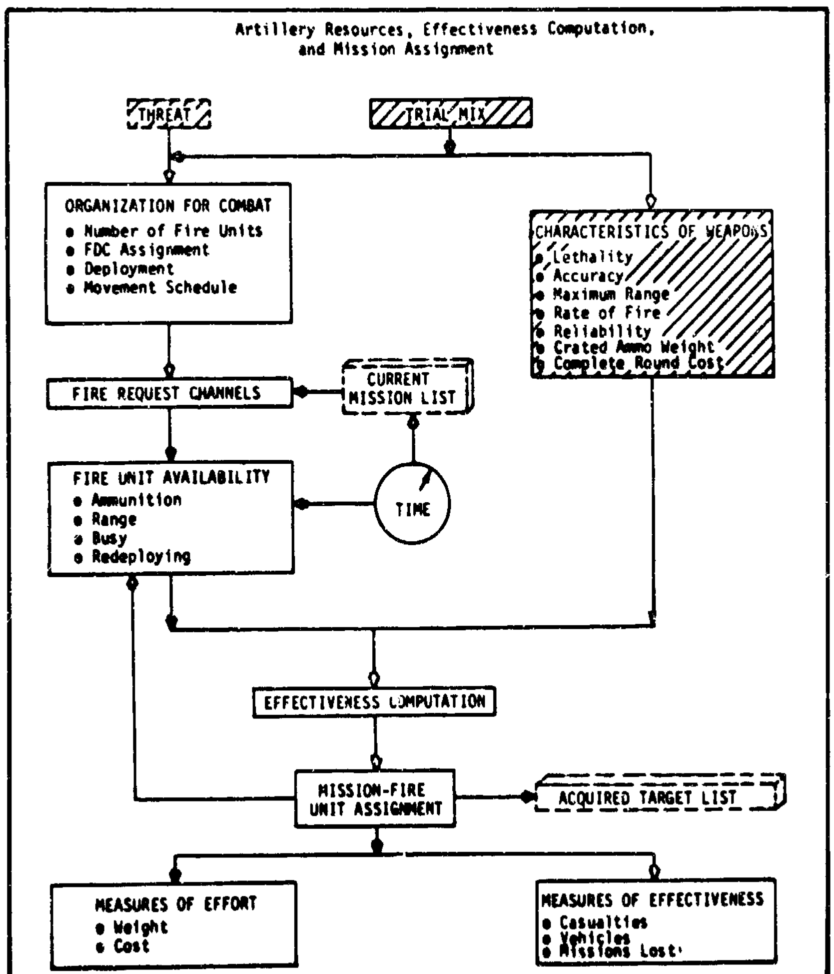

Chart 6

In addition to the characteristics of the weapons constituting a trial mix, the organization for combat of the weapons in the mix must be considered.

For each weapon in the mix, the number of fire units composed of that weapon is given. Each fire unit is assigned to an appropriate FDC. Geographic deployment of units together with a movement schedule is provided.

To process a mission from the current mission list, an assessment is made of weapon availability for each fire unit assigned to the FDC responsible for the mission. Determination is made of the number of rounds available to each fire unit for the mission based on current ammunition inventory, the unit to target range, whether the unit is conducting another mission, or whether it is redeploying.

Expenditures are computed for single fire units or combinations of fire units to attain the desired attack level on the estimated target. Number of casualties and armored vehicle damage is assessed on the actual target for the respective combinations of attacking weapons.

If one or more combinations of weapons can successfully attack the target, a predetermined criterion is used to select the best combination to be employed. The mission is performed by these units; ammunition inventories of these units are adjusted and the units are keyed to be busy for other missions occurring in the same time period. The casualties or vehicle damage inflicted on the actual target by the combination of weapons is recorded and accumulated as part of the effectiveness measures. Weight and cost of ammunition required are similarly accumulated as measures of effort.

If the mission cannot be performed by any combination of units available to an FDC, the mission is sent to the FDC at the next higher echelon for further consideration if the expected duration time allows. If the mission is at the highest echelon, it is deferred until the next time period. If the estimated duration time is such that it would have been assumed to have departed by the next time period, the mission is recorded as permanently lost. The total number of such missions is summarized as part of the effectiveness measures.

This completes the description of the simulation model. To evaluate mixes, it is necessary to define the measures to be used. A typical set of significant measures of artillery performance are shown as:

- Ammunition cost
- Ammunition weight
- Casualties inflicted

148 248 O - 68 - 10

. Armored vehicles damaged

. Missions left unperformed.

The first two are measures of effort, and the last thr:e are measures of effectiveness.

Chart 7 lists studies that have employed the time dependent model. The significant point to be noted is our most recent emphasis on studies supporting the AMC System Analysis tasks, which the older s.udies supported joint AMC/CDC efforts.

STUDIES USING TIME DEPENDENT ARTILLERY EVALUATION MODEL		
JUL 1967	CDC	OPTIMUM MIX OF ARTILLERY UNITS 1971-75
MAY 1968	CDC	LANCE COST AND EFFECTIVENESS STUDY
MAY 1968	CDC	DIVISIONAL ARTILLERY STUDY
JUN 1968	CDC	TACFIRE COST AND EFFECTIVENESS STUDY
OCT 1968	AMSAA	AN EVALUATION OF EXISTING ARTILLERY AMMUNITION ASSETS (FORTHCOMING)
NOV 1968	AMSAA	SENSITIVITY OF ARTILLERY PERFORMANCE TO VARIATIONS IN TACTICAL CONSTRAINTS (FORTHCOMING)

Chart 7

It has been found that such studies can be extremely useful in enhancing the ability of AMC to perform its mission. The studies themselves provide a virtual handbook of current data in a readily understandable form. Factor analysis using the model can provide guidance to the AMC budgeter on what areas have the most potential to improve artillery performance. By providing a peek at what others are doing, such studies have resulted in improvements in weapon characteristics. An example of this phenomenon is the competition between cannon and missile systems. Each system could borro.. the best features of the other. The net result is an overall improvement in AMC performance.

SEMIGAMING METHODOLOGY FOR DYNAMIC THREAT DESCRIPTION

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There are a number of things that must be known by the fire support weapons systems analyst. Some of the important aspects are the AMSAA approach to and derivation of *target characteristics* for fire support weapons, analysis of our *target intelligence* capabilities, and analysis of the effects of certain characteristics of the operational *environment*. Because a great variety of *potentially* applicable fire support means exist, such as mortars and missiles, naval guns and tactical aircraft, the fire support systems analyst *must* have a means to address his studies in the perspective of the total combat environment. Semigaming was originally conceived as a method for comparing the capabilities of *dissimilar*, or at least different performances in weapons in performing *similar* tasks.

Semigaming is a method developed by the United States. This method uses a series of sequential map deployment estimates called target arrays. The sequential arrays are drawn showing the commitment and movement of enemy forces over some time interval. *Enemy* forces are drawn in some detail and once their dispositions and movements are determined by assuming typical tactics, they are then recorded and fixed. Then we work out a plan for the employment of our own sensors and weapons opposing this threat. Sensor information is interpreted together with order of battle and terrain intelligence to develop fire plans. Time factors are recorded, and the intelligence analyst's estimate of target location, type and size are compared with the previously fixed data. The resultant "errors" are then recorded so that weapon performance may be degraded accordingly.

SEMIGAMING

- A SER.ES OF STEPS -
  - THREAT DEFINITION
  - PORTRAYAL OF TARGET DEPLOYMENT AND MOVEMENT
  - TARGET ACQUISITION SIMULATION
  - TARGET INTELLIGENCE ESTIMATION
- USING GAMING METHODS TO PRODUCE - A SINGLE, FIXED, BUT DYNAMIC

  THREAT DESCRIPTION
- FOR FIRE SUPPORT WEAPON EVALUATION STUDIES

Chart 1

In this talk I will be repeating some things that others have said. I ask your indulgence when I state or restate the obvious. In so doi: I want to bring out some things the AMSAA has been trying to do to overcome limitations of past studies.

The AMSAA has a small tactical operations analysis capability. The objective is to ensure that our systems analysis studies relate to the battle environment, an environment where the potential best use of some system is influenced by the methods, capabilities and limitations of human users, supporting systems, and alternative systems. The role of the tactical operations analysis study effort in AMSAA is twofold: to interpret th ser's needs or stated requirements for systems in a context that lends itself to scientific analysis, and to recognize advances in system state-of-the-art in such a way that the potential of such advances may be tested without restriction or biases that might, *unnecessarily*, be imposed by past tactical doctrine.

In 1969, the dynamic target array is widely used as the basic threat description in fire support weapon evaluation studies. It provides a means for the weapon systems analyst to consider factors of target size and hardness, weapon-to-target range, target frequency of occurence, accuracy of target information from the weapon's point of view, echelon information reported and the availability and duration of targets as a function of time.

The enemy threat employed in many past cost-effectiveness studies has consisted of one, or at the most, several static target arrays (or tactical deployment estimates) of a potential enemy, frozen at some point in time.

The main difference between this static array and a dynamic array is that the dynamic array consists of several such instantaneous deployments in succession which depict the significant movement on the battlefield as potential targets maneuver.

Adequate derivation of dynamic factors is involved and time consuming. Thus, in many past studies it has been assumed that one weapon could be affected about as much as another by such dynamic factors. In comparisons of different systems these factors might not affect each weapon in the same manner. Time is important because the ability of a system to attack targets is a function of the duration of the target when deployed, the speed of the target when moving, and the hour at which attack is desired.

As an example, an artillery missile can usually respond to targets acquired at night. An aircraft's capability severely reduced at night, and must often hope that the targets are still there in the morning, or later if the weather is unfavorable. *Conversely*, the aircraft can attack targets when they are most easily acquired, while moving. The missile must wait until they halt, and hope that they can be found.

No *meaningful* analysis of the advantages of one weapon system over another in a competitive role can be accomplished with only qualitative considerations of dynamic factors. Their value must be determined and examined thoroughly and quantitatively.

The most important attribute of the dynamic target array produced through semigaming is that, despite its timedependent characteristic, it provides a *common base* for evaluation of alternative weapons or alternative mixes of weapons. Variations in weapon capability can be evaluated *without the need to generate new threat information* for each alternative weapon concept.

SEQUENTIAL DEPLOYMENT ESTIMATES

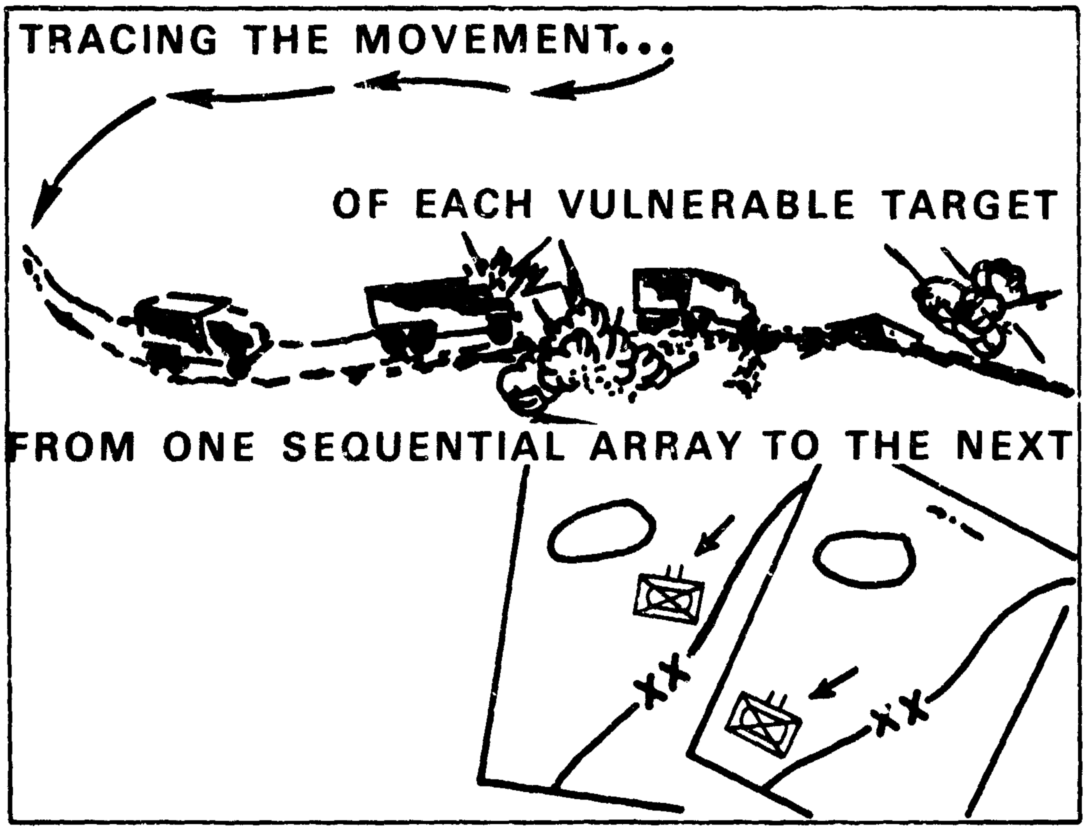

Chart 2

Semigaming is an open methodology which applies a mixture of gaming rules and professional experience to predict the interactions of opposing forces. Significant changes in the overall posture of the enemy (threat) force are recorded in detail on map overlays, and records are made of the events that occur during the periods of time between the mapped records, in tabular form. These include detailed records of potential target duration and movement from one position on the battlefield to another. Following the completion of this series of steps, certain aspects of the friendly force deployment are also recorded.

The record of information concerning friendly activities has varied in our studies during the past few years. It is a function of both the needs of a particular study and available time.

For the legal mix-formerly Redleg study, which will be discussed in the next presentation, records were made of United States combat unit positions down to brigade, and alternative artillery firing positions were selected and recorded. In addition the position and periods of operation of each friendly target acquisition sensor were recorded in detail.

The target acquisition analysis is facilitated by the time-dependent characteristics of the target array.

FAMILY OF TARGET ACQUISITION SENSORS
FORWARD OBSERVER OR OP
NIGHT VISION
FLASH AND SOUND RANGING
COUNTERMORTAR RADAR
COUNTERBATTERY RADAR
GROUND SURVEILLANCE RADAR
VISUAL AIRBORNE TARGET LOCATION SYSTEM
LONG RANGE PATROLS
ARMY SECURITY AGENCY (ASA) SYSTEM - SIGINT
USAF AIRCRAFT, WITH IR, PHOTO

Chart 3

Data are accumulated on target acquisition means available to a United States field army for each sensor; the data gathered include the echelon at which it is employed, as well as the number available for employment, range, accuracy, and quality of target element identification together with limiting factors, such as the effects of fog, rain, darkness, and terrain obstacles, and the time required for information transmission, processing, and retransmission to a using fire support system.

The initial step in this phase of the semigaming method is the creation of surveillance plans for guiding the employment of the various sensors. These are prepared through the introduction of initial artifical intelligence and are based heavily on map analysis and a level of order-of-battle information that could be expected to be available during combat.

SEMIGAMING TOOLS

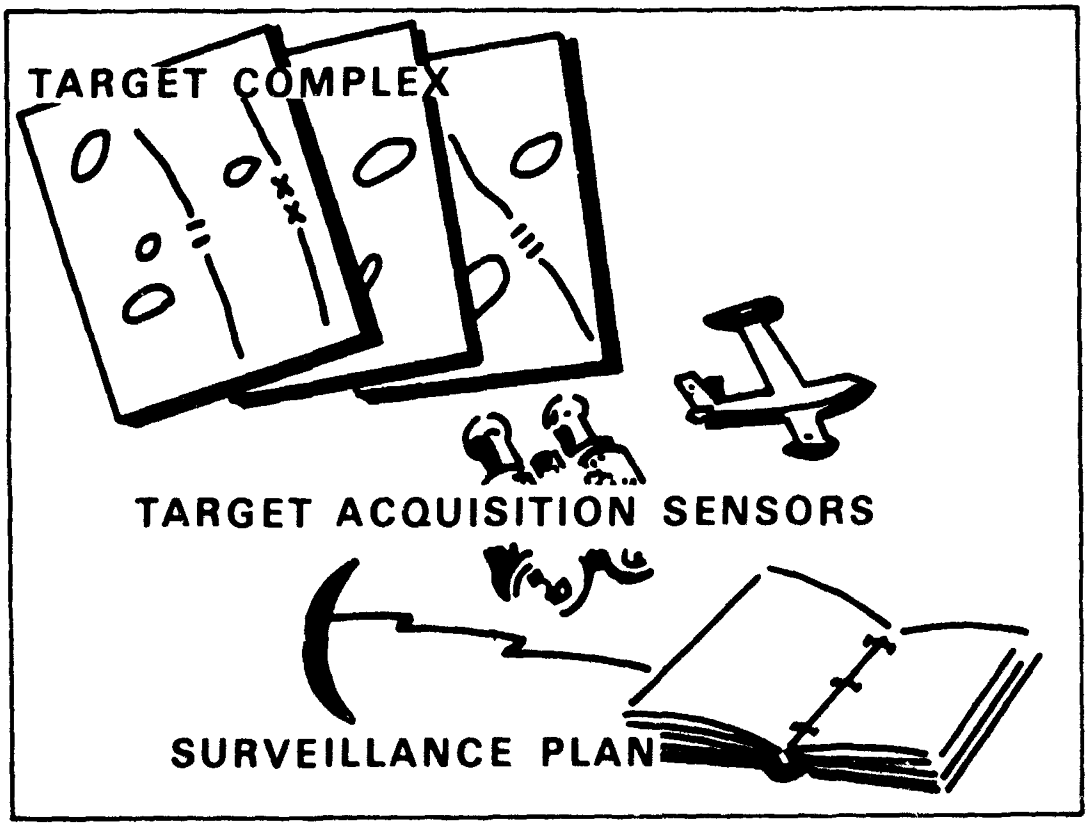

Chart 4

In estimating target acquisition information that will be available to the future field commander, we try to assess intelligence in the same manner as intelligence data presented to the tactical commander would be assessed. We separate the analysis of data obtained through sensors from the over-all intelligence analysis. Target intelligence is developed by analysts who are exposed only to a description of the general tactical situation, the fragmentary information which sensors provide, order-of-battle information, and maps. These analysts are not permitted to compare their information with actual deployment information shown on threat overlays, but they are permitted to alter the surveillance plan whenever they wish.

Next, the sensors are "employed" against the target arrays to determine a list of targets vulnerable to detection by various means. Lists are compiled showing each target vulnerable to detection, together with the appropriate sensors.

Target duration from the original record is then compared with these data, and the list of vulnerable targets prepared in the previous step is accordingly modified to reflect only those target-sensor combinations which *can* result in target detection.

At this point *target models* for each type of target are introduced. A target model is a detailed presentation of the target and terrain on which it is located in such a manner that it can be analyzed to determine the parts subject to detection by specific sensors.

Environmental degradation factors are then introduced. Sensor-target combinations subject to line-of-sight restrictions are resolved in the absolute sense; i.e., a map analysis is performed to determine whether the target is visible each time a sensor "looks" in its direction. The effects of vegetation, darkness, and atmospheric moisture are determined.

ENVIRONMENTAL DEGRADATION FACTORS

INTERVISIBILITY
WEATHER
LIGHT/DARKNESS
VEGETATION
BATTLEFIELD CONDITIONS

Chart 5

Each sensor-target combination is evaluated in like manner. Width of sensor coverage on the ground is analyzed on large-scale overlays (1:6,250) of each target model. The preliminary acquisition lists are then revised, incorporating these degradations. These revised lists are then analyzed by a separate group of analysts whose task is to evaluate the data obtainable from sensors in the same manner that intelligence personnel in the field would process target information to obtain target intelligence.

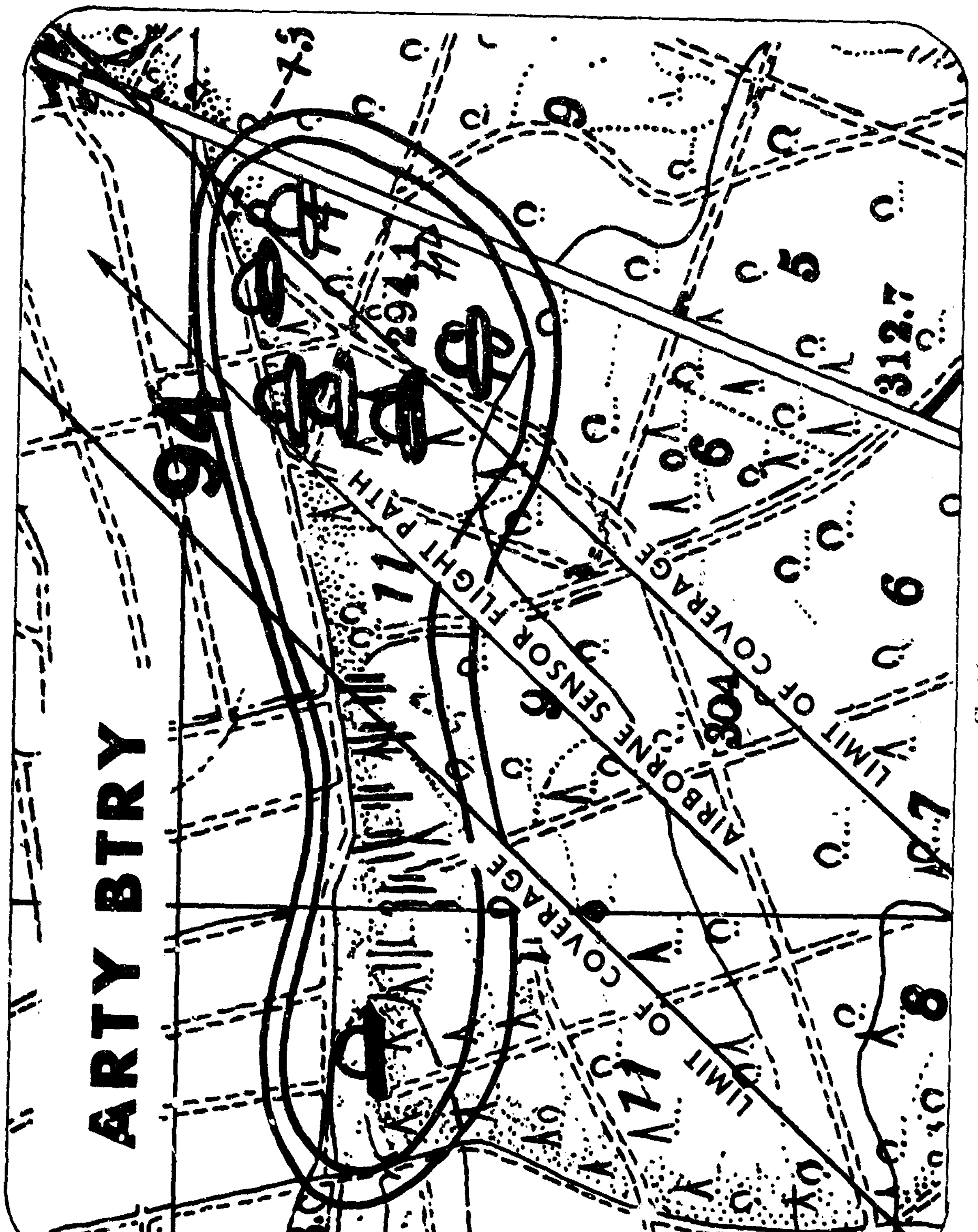
ARTY BTRY
94
AIRBORNE SENSOR FLIGHT PATH
LIMIT OF COVERAGE
LIMIT OF COVERAGE
304
312.7

Chart 6

This group prepares an "estimated" fire-plan which includes: target type, target center location, target size, and it lists the sensor(s) that provided the initial information. The appropriate information routing is reviewed as a final check on processing time in light of planned command and control procedures. A location error is determined for each target based on coordinates chosen by the intelligence team, compared with the actual center as originally recorded from the target arrays. This error may be related to sensor capabilities and map accuracy alone. In a majority of cases where the target identification may be expected to be of good quality, however, the intelligence analyst can improve on sensor accuracy throu~h a careful study of the battlefield map.

TARGET COMPLEX DATA

TARGET NUMBER
NUMBER OF TIMES ACQUIRED
TIME TARGET INFORMATION AVAILABLE
ESTIMATED TYPE
ESTIMATED DURATION
ESTIMATED LOCATION
ESTIMATED RADIUS
LOCATION ACCURACY
SENSORS THAT ACQUIRE
ACTUAL TYPE
ACTUAL DURATION
ACTUAL LOCATION
ACTUAL SIZE
UNIT DESIGNATION
COMPOSITION

Chart 7

The product, a list of potential fire missions ordered by time of target acquisition, may be compared with the "actual" threat as originally shown, and the effects of fires on targets estimated by the target intelligence team can be assessed against the actual targets.

I'd like to point out that the data that can be obtained through semigaming support AMC studies in many ways.

The applications shown on the chart relate *primarily* to data based on weapon and sensor employment.

MUNITIONS	-	VARIATION IN TARGET POSTURE
	-	VARIATION IN TARGET ENVIRONMENT
FIRE SUPPORT WEAPONS	-	VARIATION IN TARGET TYPE
	-	TARGET INTELLIGENCE CAPABILITIES
FIGHTING VEHICLES	-	FREQUENCY OF ENCOUNTER
COMMUNICATION SYSTEMS	-	FREQUENCY OF MESSAGE
	-	REDUNDANCY REQUIREMENTS
TARGET SENSORS	-	VARIATION IN TARGET ENVIRONMENT
SMALL ARMS	-	CRITICAL ENGAGEMENTS
LOGISTICS VEHICLES	-	FREQUENCY OF TERRAINS ENCOUNTERED

Chart 8

This audience is fully aware of the long list of drawbacks to war gaming. One of them has been the high cost of extensive game replications when many alternative tactics or weapons or opposing forces or logistical concepts and so on must be investigated. I believe that valid systems analysis studies, supporting the AMC mission, can be pursued with the semigaming method at considerable saving of cost and time.

SYSTEMS ANALYSIS CAPABILITIES AT THE US ARMY ELECTRONICS COMMAND

Daniel Salvano
Chief, Systems Analysis Division, USAECOM
USA Electronics Command
Fort Monmouth, New Jersey

The ECOM Systems/Cost Analysis Office is more than pleased to participate in this first AMC Systems Analysis Symposium. We are also pleased to have had the opportunity to discuss programs of mutual interest in these past 2 days. For those participants who are not familiar with the Electronics Command, I would like to take a few minutes to describe briefly ECOM's organization and scope of activities.

ECOM is located at Fort Monmouth, New Jersey, and is under the command of Maj. General William B. Latta. As can be seen in Chart 1, ECOM's mission covers a wide spectrum of Communications-Electronics activities, such as electronic components and power sources, communications, avionics, atmospheric sciences, electronic warfare, combat surveillance, and night vision. It also includes other typical operating and support activities, such as Research and Development, Production and Procurement, Maintenance Engineering, Product Assessment and Value Engineering.

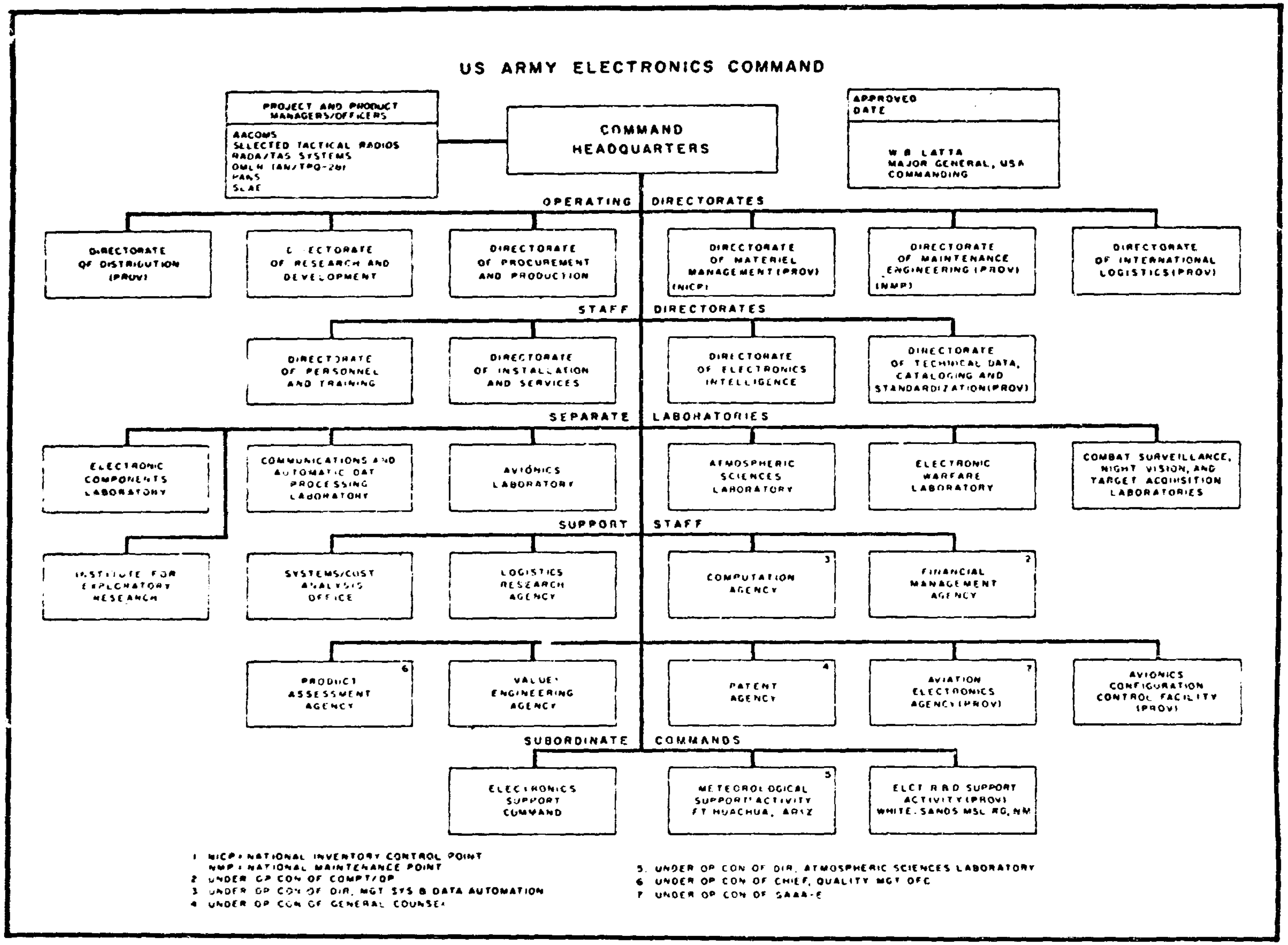
US ARMY ELECTRONICS COMMAND
PROJECT AND PRODUCT MANAGERS/OFFICERS
AACOMS
SELECTED TACTICAL RADIOS
RADA/TAS SYSTEMS
OMLH (AN/TPQ-28)
PANS
SLAE
COMMAND HEADQUARTERS
APPROVED
DATE
W B LATTA
MAJOR GENERAL, USA
COMMANDING
OPERATING DIRECTORATES
DIRECTORATE OF DISTRIBUTION (PROV)
DIRECTORATE OF RESEARCH AND DEVELOPMENT
DIRECTORATE OF PROCUREMENT AND PRODUCTION
DIRECTORATE OF MATERIEL MANAGEMENT (PROV) (NICP)
DIRECTORATE OF MAINTENANCE ENGINEERING (PROV) (NMP)
DIRECTORATE OF INTERNATIONAL LOGISTICS (PROV)
STAFF DIRECTORATES
DIRECTORATE OF PERSONNEL AND TRAINING
DIRECTORATE OF INSTALLATION AND SERVICES
DIRECTORATE OF ELECTRONICS INTELLIGENCE
DIRECTORATE OF TECHNICAL DATA, CATALOGING AND STANDARDIZATION (PROV)
SEPARATE LABORATORIES
ELECTRONIC COMPONENTS LABORATORY
COMMUNICATIONS AND AUTOMATIC DAT PROCESSING LABORATORY
AVIONICS LABORATORY
ATMOSPHERIC SCIENCES LABORATORY
ELECTRONIC WARFARE LABORATORY
COMBAT SURVEILLANCE, NIGHT VISION, AND TARGET ACQUISITION LABORATORIES
INSTITUTE FOR EXPLORATORY RESEARCH
SUPPORT STAFF
SYSTEMS/COST ANALYSIS OFFICE
LOGISTICS RESEARCH AGENCY
COMPUTATION AGENCY 3
FINANCIAL MANAGEMENT AGENCY 2
PRODUCT ASSESSMENT AGENCY 6
VALUE ENGINEERING AGENCY
PATENT AGENCY 4
AVIATION ELECTRONICS AGENCY (PROV) 7
AVIONICS CONFIGURATION CONTROL FACILITY (PROV)
SUBORDINATE COMMANDS
ELECTRONICS SUPPORT COMMAND
METEOROLOGICAL SUPPORT ACTIVITY FT HUACHUA, ARIZ 5
ELCT R&D SUPPORT ACTIVITY (PROV) WHITE SANDS MSL RG, NM
1 NICP: NATIONAL INVENTORY CONTROL POINT
NMP: NATIONAL MAINTENANCE POINT
2 UNDER OP CON OF COMPT/DP
3 UNDER OP CON OF DIR, MGT SYS & DATA AUTOMATION
4 UNDER OP CON OF GENERAL COUNSEL
5. UNDER OP CON OF DIR, ATMOSPHERIC SCIENCES LABORATORY
6 UNDER OP CON OF CHIEF, QUALITY MGT OFC
7 UNDER OP CON OF SAAA-E

Chart 1

ECOM employs approximately 13,000 people with major activities located in Fort Monmouth, New Jersey; Philadelphia, Pennsylvania; Fort Belvoir, Virginia; and White Sands, New Mexico. Total ECOM business is estimated at about $1.5 billion, with approximately $275 million allocated for R&D activities. This is big business, and it is estimated that the Systems Analysis workload can easily support about 50 personnel required for conducting inhouse studies. As you can see from Chart 2, we estimate on an annual basis at least 5 to 10 major systems analysis studies, and approximately 10 to 15 smaller cost-effectiveness studies. It is apparent that a savings of $1 or 2 million on any one system study would more than pay for the support of such an activity. This amount represents only a small fraction, about one-tenth percent of the total ECOM business and appears to be a modest investment in view of the anticipated returns.

MAJOR CAPABILITIES

1.	TOTAL ECOM PERSONNEL	13,300 PERSONNEL
	NUMBER OF ENGINEERING PERSONNEL	4,100 PERSONNEL
2.	RDT&E FACILITIES - INVESTMENT	$1.2 BILLION
3.	TOTAL ECOM BUSINESS	$1.4 BILLION
	RDT&E	$275 MILLION
	PEMA	$1 BILLION
	O&MA	$135 MILLION
4.	CURRENT MILITARY REQUIREMENTS (QMDO/QMR/SDR)	125 APPROVED DOCUMENTS
5.	CURRENT CM^2P'S	96 ITEMS @ $740 MILLION
6.	ANNUAL SA/CE WORKLOAD	10 MAJOR SYSTEM STUDIES
		15 SMALLER C/E STUDIES

Chart 2

Additionally, it is believed that a competent Systems Analysis capability, at ECOM, would have even greater impact on other major Army systems, because of the multimission aspects of ECOM commodities. This is apparent from my next chart and illustrates how the command-control, and Communications-Electronics issues, cut-across and permeate most combat missions such as moving, shooting and the gathering of intelligence and other data. Note on the left hand side of Chart 3, I have listed some of the major ECOM commodities. It can be seen, that these commodity areas, directly support major Army Weapon Systems or subsystems, such as AAFSS, a Division Communications System as in the case of RADA and for the targeting of ground missiles and long-range artillery, as in the case of MOHAWK. There is no question that the Communications-Electronic issues, constitute a vital link, and may possibly be the crucial systems analysis criteria for evaluating the combat-effectiveness capabilities, of the Army's major weapon systems. The Army's Force Development Plan (AFDP) for the period 1966-85 lends credibility to this hypothesis. Of 78 modernization items, 18 items, or about 23 percent of this total, are the development responsibility of ECOM. Forty-seven additional items, or about 60 percent more of the total, are supported by ECOM.

ECOM COMMODITY AREAS AND TYPICAL SYSTEMS/SUBSYSTEMS

COMMODITY AREA	TYPICAL SYSTEM/SUBSYSTEM	TYPICAL FIGURES OF MERIT
AVIONICS	AAFSS	1. EXPECTED NUMBER OF CORRECT WEAPON ASSIGNMENTS 2. EXPECTED NUMBER OF ACCURAGE POSITIONINGS 3. EXPECTED NUMBER OF MISSIONS PER MINUTE
COMMUNICATIONS/ADP	MALLARD - RADA	1. AVAILABILITY OF GRADES OF SERVICE 2. PERCENTAGE OF DELIVERABLE MESSAGES DELIVERED AFTER RANDOM DESTRUCTION OF U COMPONENTS
	COMMAND & CONTROL OF SAM-D'S	1. PROBABILITY OF INFORMATION LOSS 2. PROBABILITY OF CONTROLING FRIENDLY AIRCRAFT GIVEN NO ENEMY AIRCRAFT ARE ENGAGED 3. PROBABILITY OF SUCCESSFUL VECTORING INTERCEPTS AGAINST U ENEMY AIRCRAFT
COMBAT SURVEILLANCE/NIGHT VISION/TARGET ACQUISITION	MOHAWK/SURVEILLANCE RADAR	1. EXPECTED NUMBER OF TARGET DETECTIONS 2. EXPECTED NUMBER OF TARGET TRACKS 3. EXPECTED NUMBER OF MISSIONS PER MONTH
ELECTRONICS WARFARE	PORTABLE ELINT SYSTEM	1. PROBABILITY OF SIGNAL DETECTION 2. PROBABILITY OF SIGNAL COLLECTION
ELECTRONIC COMPONENTS	POWER SOURCES	1. PROBABILITY OF SUCCESSFULLY PROVIDING POWER FOR TIME PERIOD INVOLVED

Chart 3

The cost-effectiveness of an infantry division, an AAFSS, or a lance-type weapon system is, therefore, critically dependent upon the performance of ECOM commodities or subsystems, which fortunately, have identifiable, independent functions. Consequently, total mission success of major Army systems can be readily identified and related to ECOM subsystems or equipments. An example of some of these relationships is shown under the column entitled, "Typical Figures of Merit".

The primary Systems Analysis activity at ECOM is a division of the Systems/Cost Analysis Office and is under the operational control of the Comptroller and Director of Programs, ECOM. It has an authorized TDA of 20 spaces, with 15 personnel on board and 5 vacancies under recruitment. It should be noted that all 20 spaces have been provided from existing ECOM resources; however, we have submitted a PCR to AMC for a total systems analysis staffing of 45 spaces.

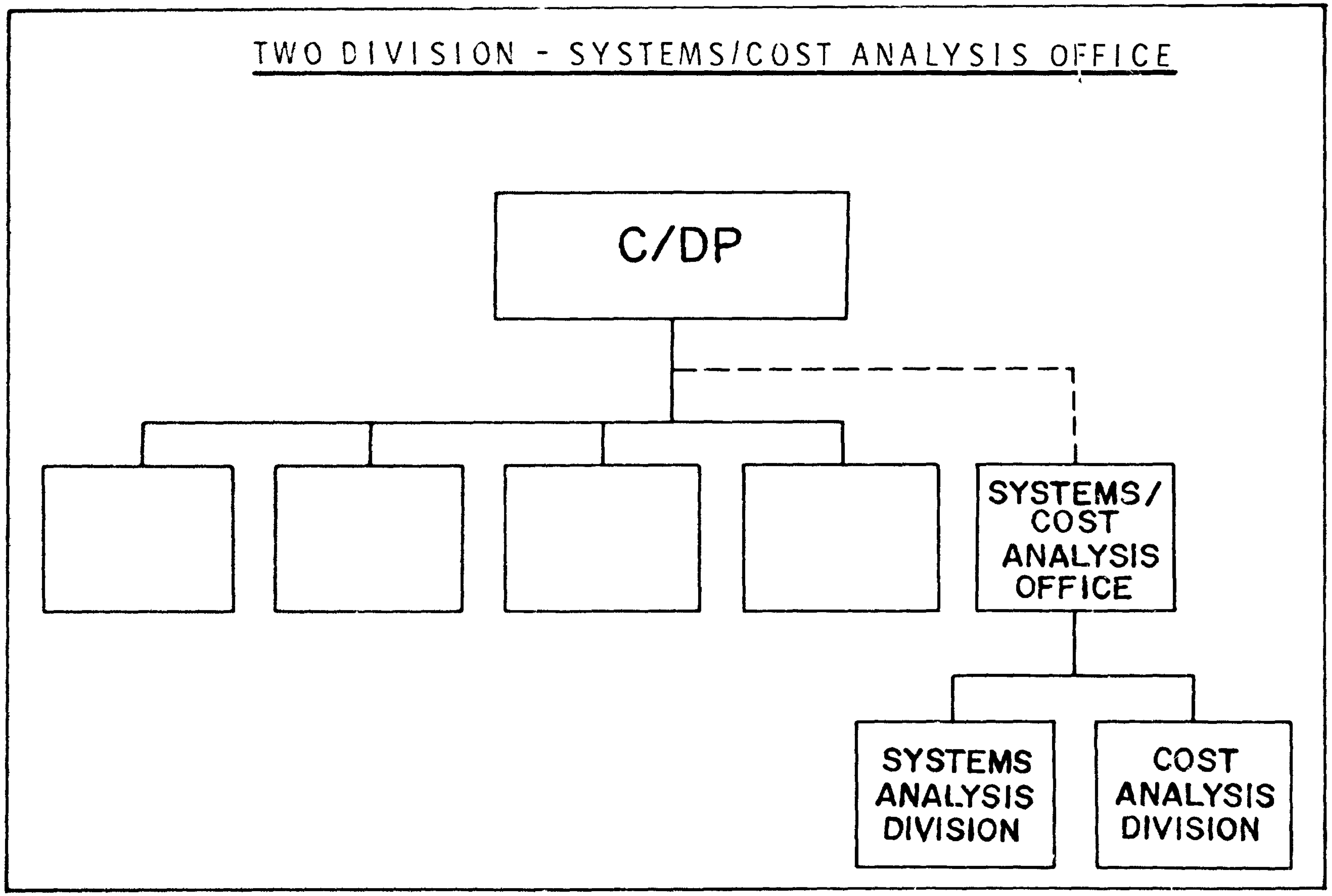
TWO DIVISION - SYSTEMS/COST ANALYSIS OFFICE
C/DP
SYSTEMS/ COST ANALYSIS OFFICE
SYSTEMS ANALYSIS DIVISION
COST ANALYSIS DIVISION

Chart 4

Note that four of these five vacancies are for operations research analysts. We have found it extremely difficult to recruit *qualified* analysts for these positions, and we anticipate that this problem will continue to exist on an Army-wide basis for considerable time.

MANPOWER RESOURCES

(EXISTING & PROJECTED)

		SYSTEMS ANALYSIS
	ELCT ENGR	7 (1)
	OP RSCH ANAL	3 (4)
ON BOARD	PROG ANAL	-
AND	MATHEMATICIAN	-
COMMITTED	STATISTICIAN	-
	ECONOMISTS	-
	COMM SPEC	2
	CLERICAL	3
	TOTAL	15 (5)
	INCREASE PENDING PCR APPROVAL	25
		45

Chart 5

The present breakout of spaces for the Systems Analysis Division is listed on my next chart and shows the type of personnel and total strength of on-board and committed spaces. About 50 percent of our professional personnel have advanced degrees.

My next chart lists the major current and projected workload for the United States Army Electronics Command. It should be stated that this does not include all of the Systems Analysis effort at ECOM.

USAECOM

SYSTEMS ANALYSIS/COST-EFFECTIVENESS STUDIES

	Concept Formulation	Development & Production	Supporting Studies
A. Studies in Progress			
1. Methodology for Systems Analysis of MALLARD System			X
2. Project MALLARD System Study	X		
3. Lightweight Contingency Station for SCS		X	
4. Omnidirectional Mortar Locator AN/TPQ-28		X	
5. Cost Effectiveness Lectures [illegible]			X
6. Systems Analysis Criteria and Methodology Study			X
7. Army Area Communications System Study		X	
8. Study of Computer Controlled Automatic Test Equipment (CATE)		X	
9. RADA Cost-Effectiveness Study		X	
10. Utility Tactical Transport Assault System (UTTAS)	X		
11. Army Tactical Communications Study (ATACOM)			X
12. Depot Installed Maintenance Automatic Test Equipment (DIMATE)		X	
B. Studies Completed			
1. Tactical Satellite Communications (TACSATCOM) Preliminary Cost-Effectiveness Study	X		
2. Army Tactical Airspace Regulation System (ATARS) Parametric and Systems Synthesis Study	X		
3. Systems Analysis Study Micro Electronics Impact on Communications-Electronics Systems			X
C. Studies To Be Initiated, Planned or Recommended			
1. Tactical Satellite Communications (TACSATCOM)		X	
2. Tactical Radio Communications System	X		
3. Combined Positioning and Navigation System	X		
4. Manned Aerial Vehicles for Surveillance (MAVS)	X		
5. Multi Channel Transmission (PCM) Cost-Effectiveness Study		X	
6. Joint Services Scenario Amphibious Model			X
7. Semi Automatic Switch		X	
8. Forward Area Teletypewriter (FATT)	X		
9. Collision Obstacle Terrain Avoidance System (COTAWS)	X		

Chart 6

Note that ECOM is working on 12 major studies, has completed three, and plans to initiate nine additional studies. We have listed these studies under three major headings: concept formulation, development and production, and supporting type studies.

An example of a study that supports the concept formulation phase is our recent inhouse cost-effectiveness study on TACSATCOM. The results of this pilot study were presented to the AMC Materiel Studies Review Committee in August, and the final preliminary study report was submitted to OCRD in September 1968. Other major studies supporting the concept formulation phase are the MALLARD System Studies at RCA and Sylvania and the Manned Aerial Vehicle for Surveillance (MAVS).

Another inhouse project (this one supporting major development and production decisions) is a Cost/Worth Study for a Lightweight Contingency Station for the Defense Communications Agency. The purpose of this study is to determine the cost and worth of reducing the size and weight of conventional DCS contingency stations by the maximum utilization of integrated circuit technology and the latest techniques in modular construction. Although this study has experienced some delays, it is expected to be satisfactorily completed by May 1969.

Other items, such as Methodology for MALLARD and the Cost-Effectiveness Lecture Series and Handbook, support the development of a competent systems analysis capability, and are required to provide the necessary analytical tools, techniques, and models, for evaluating alternative design concepts in order to allow the decision makers, to make a valued judgment on major materiel programs. A current inhouse study which also comes under this category, is the Army Tactical Communication Study (ATCOM), which is a Department of the Army, Chief of Staff directed study. The objective of this study is to provide a continuing capability within the Army to evaluate and present cost/capabilities of tactical communication equipments/systems in order to provide a sound basis, for making and justifying R&D and PEMA plans, and program decisions.

The ECOM Systems/Cost Analysis Office is now undergoing reorganization. It is planned to re-structure this office with four divisions as shown on this chart. This type organization is considered more compatible with other AMC-wide activities, and provides for more effective utilization of personnel. An MTDA is presently being prepared by ECOM, and will be forwarded to AMC for approval in the near future. In the proposed four division structure:

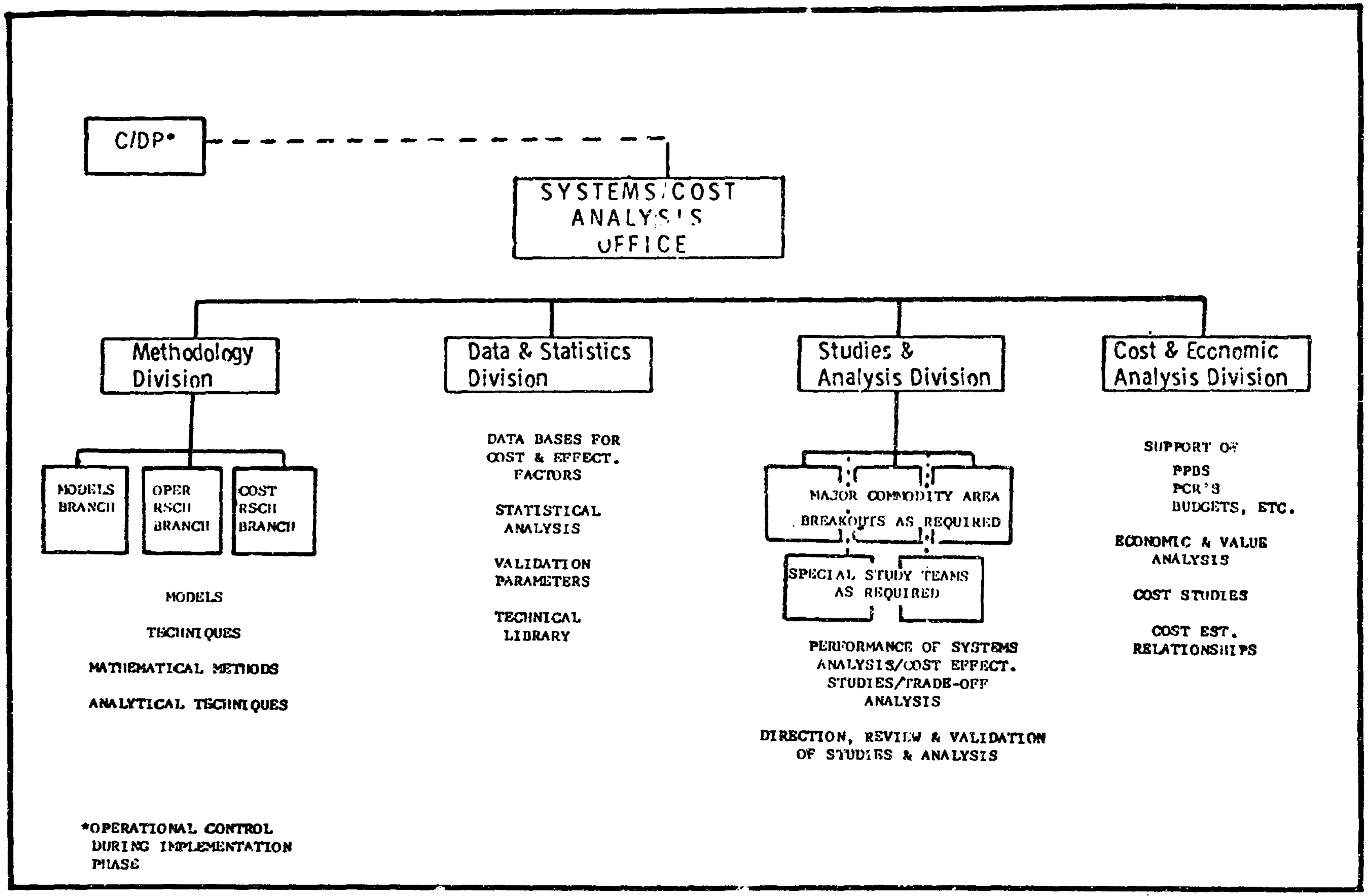
C/DP*
SYSTEMS/COST ANALYSIS OFFICE
Methodology Division
MODELS BRANCH
OPER RSCH BRANCH
COST RSCH BRANCH
MODELS
TECHNIQUES
MATHEMATICAL METHODS
ANALYTICAL TECHNIQUES
Data & Statistics Division
DATA BASES FOR COST & EFFECT. FACTORS
STATISTICAL ANALYSIS
VALIDATION PARAMETERS
TECHNICAL LIBRARY
Studies & Analysis Division
MAJOR COMMODITY AREA BREAKOUTS AS REQUIRED
SPECIAL STUDY TEAMS AS REQUIRED
PERFORMANCE OF SYSTEMS ANALYSIS/COST EFFECT. STUDIES/TRADE-OFF ANALYSIS
DIRECTION, REVIEW & VALIDATION OF STUDIES & ANALYSIS
Cost & Economic Analysis Division
SUPPORT OF
PPDS
PCR'S
BUDGETS, ETC.
ECONOMIC & VALUE ANALYSIS
COST STUDIES
COST EST. RELATIONSHIPS
*OPERATIONAL CONTROL DURING IMPLEMENTATION PHASE

Chart 7

My next chart shows a realignment of manpower resources from both the Systems Analysis and the Cost Analysis Division required to satisfy the proposed four-division structure. The total of eighty spaces shown includes both the current authorization of 45 spaces, (i.e. 20 from the Systems Analysis Division and 25 from the Cost Analysis Division), plus the anticipated spaces from both the systems and cost analysis PCR's.

MANPOWER RESOURCES
(EXISTING & PROJECTED)

		SYSTEMS ANALYSIS	COST ANALYSIS
ON BOARD AND COMMITTED	ELEC ENGR	9 (1)	5
	OPER RES	3 (2)	1 (1)
	PROG ANALYSTS	-	5
	MATHEMATICIAN	-	3 (2)
	STATISTICIAN	-	2
	ECONOMISTS	-	2 (1)
	COMM SPEC	1	-
	CLERICAL	4	3
	TOTAL	17 (3)	21* (4)
Additionally authorized (being recruited)		-	5
Increase pending PCR approval		25	5
		45	35

*Includes two military

Chart 8

Although our rate of progress has been slow over the past two years, we do have a large program effort underway and we have developed the cadre for a competent systems analysis capability primarily within ECOM resources. Consequently, in spite of what was said DA and AMC approval of ECOM's proposed Systems Analysis staffing PCR, would go a long way toward accomplishing the study programs directed by DA and AMC.

Additionally, timely approval by AMC of ECOM's proposed restructuring of the Systems and Cost Analysis Office to a four-division structure, will significantly improve the overall effectiveness of our inhouse study capabilities, as well as help our recruiting efforts to obtain qualified analysts.

Finally, there is a need for the establishment of an overall AMC-wide RDT&E project structure, and program authority, for continued and sustained support of systems analysis research efforts which *cannot* be supported by Operation, Maintenance and Allowances funds.

EFFECTIVENESS ANALYSIS OF COMMON-USER COMMUNICATION SYSTEM

Michael A. Benanti
Chief, Systems Analysis Methodology Branch
USA Electronics Command
Fort Monmouth, New Jersey

The subject of my talk is the Army's common-user communication system. This is something like the commercial telephone party-line where there are many more people wanting to talk to each other than there are telephone channels. The system is therefore shared, sometimes at great inconvenience. In the Army's case we have, instead of inconvenience, an adverse effect on the ability to conduct successful military operations. An improvement in the Army's common-user system is constantly sought by commanders. No small R&D effort is directed toward this improvement. Related to this effort is the need to analyze and weigh effectiveness or determine worth. This discussion will address one approach to conducting such an analysis.

This composite deployment (Chart 1) of a typical brigade headquarters identifies the command staff sections and the communication support section. There are two multi-channel radio links interconnecting the brigade with its next higher command (division). These radio links provide communication channels which are shared by the brigade command and his operations, intelligence, personnel and logistical staff officers and other staff elements, such as artillery, air defense, and aviation. This communication system is used to coordinate and control the brigade, tactical missions, and provide for logistical support.

Coordination with higher headquarters is accomplished through the radio system shown on the hill, the bulk of the channels in these systems are common-user, or shared by command staff elements.

Although this deployment is typical of a brigade headquarters, similar communication requirements exist throughout combat and combat support echelons of the Army in the field.

These other requirements, taken together, call for a much larger communications complex than the one we see here. They are called signal centers.

Before we get on with our description of common-user systems, please look at Chart 2. We are looking ahead to give you some sense of what might go into the makeup of larger

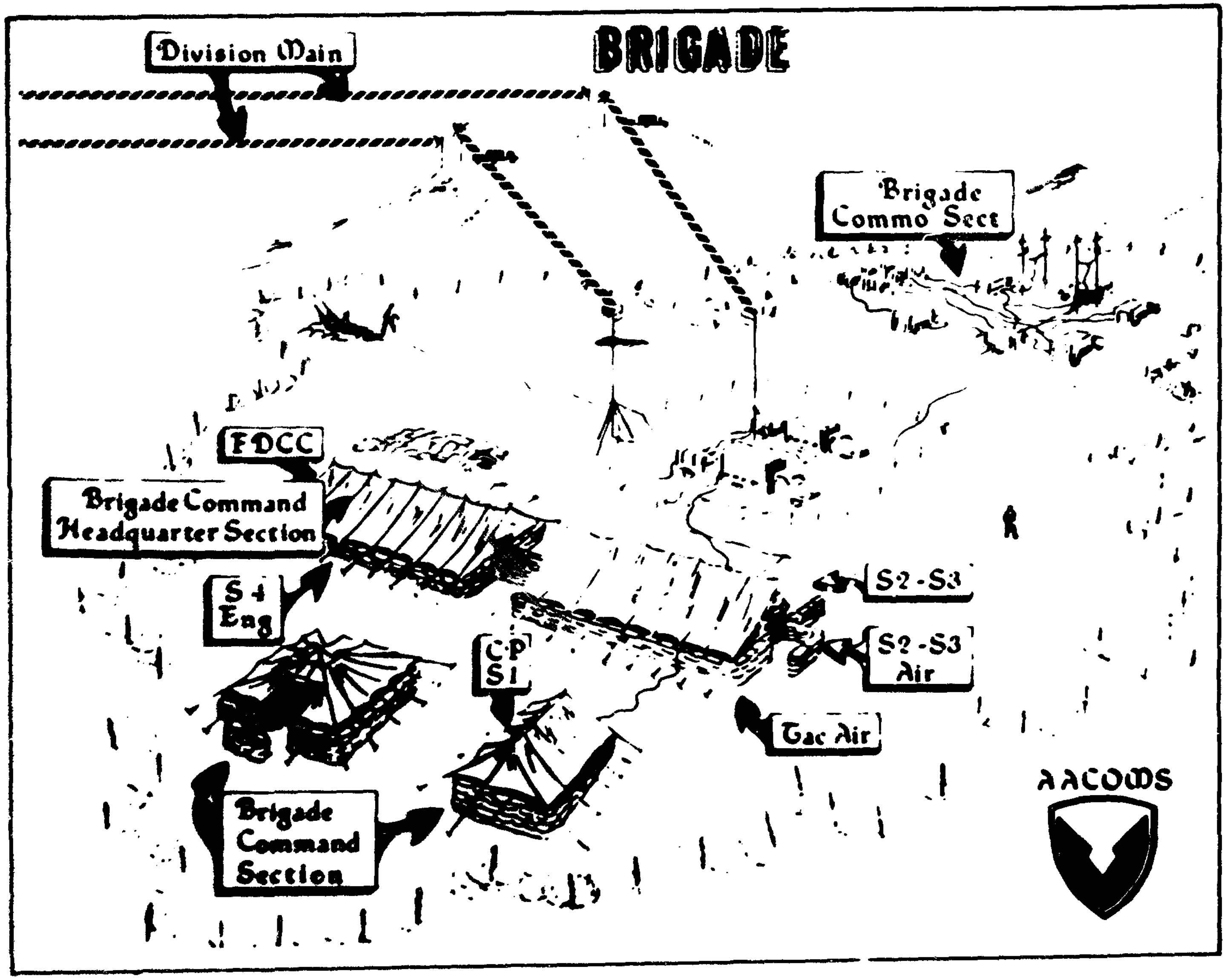
BRIGADE
Division Main
Brigade Commo Sect
FDCC
Brigade Command Headquarter Section
S-4 Eng
CP S1
S2-S3
S2-S3 Air
Tac Air
Brigade Command Section
AACOMS

Chart 1

signal centers, larger than the one we saw on the hill in the previous slide. The radio shots to the left and right are the links to other main signal centers like this one. The common-user circuits are contained in these vans.

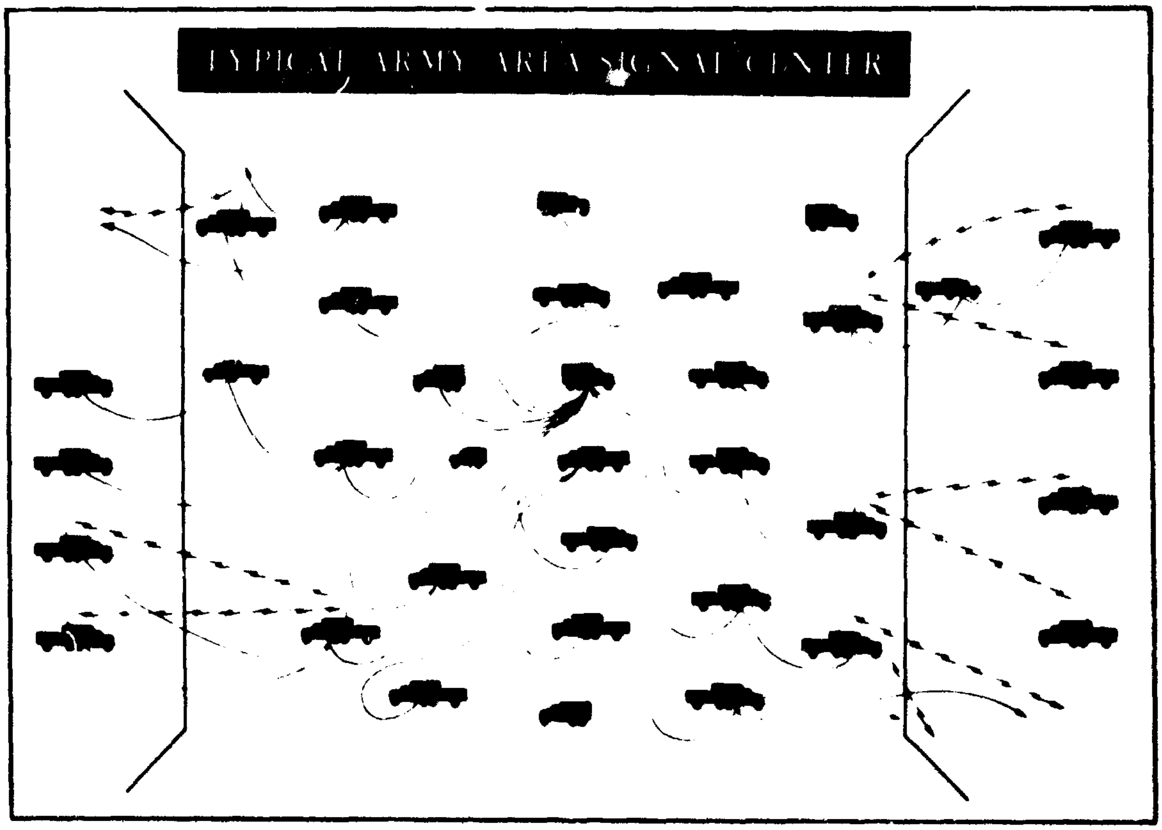

Chart 2

Now, in Chart 3, we see these same large signal centers linked together into a network. A two-Corps Army network may look something like this system. The large circles are communication centers or nodes, the lines interconnecting these nodes represent multi-channel communication links. The smaller circles and the lines to the nodes represent subscriber access systems. Since many subscribers in one area may have to transact business with groups of subscribers in another area, there will be competition for communication channels within each of the links of the system; i.e. first over the access link, then through the nodal link and then through another access link to the described subscriber. If you can visualize this competition for channels going on throughout the network, then you can realize the Army's common-user communication problem. The number of channels available in the links are limited, and a subscriber wishing to be connected with someone else is really engaged in a game of chance. The probability of achieving success is dependent upon channel capacity, and system design. The reason we emphasize this inherent system deficiency, is that system performance can be improved as a result of analysis. We are going to note one approach to this analysis. Before we move on, let us consider the line in the center of this network. Here is a case where A calls B . . . . . . etc . . . . . .etc.

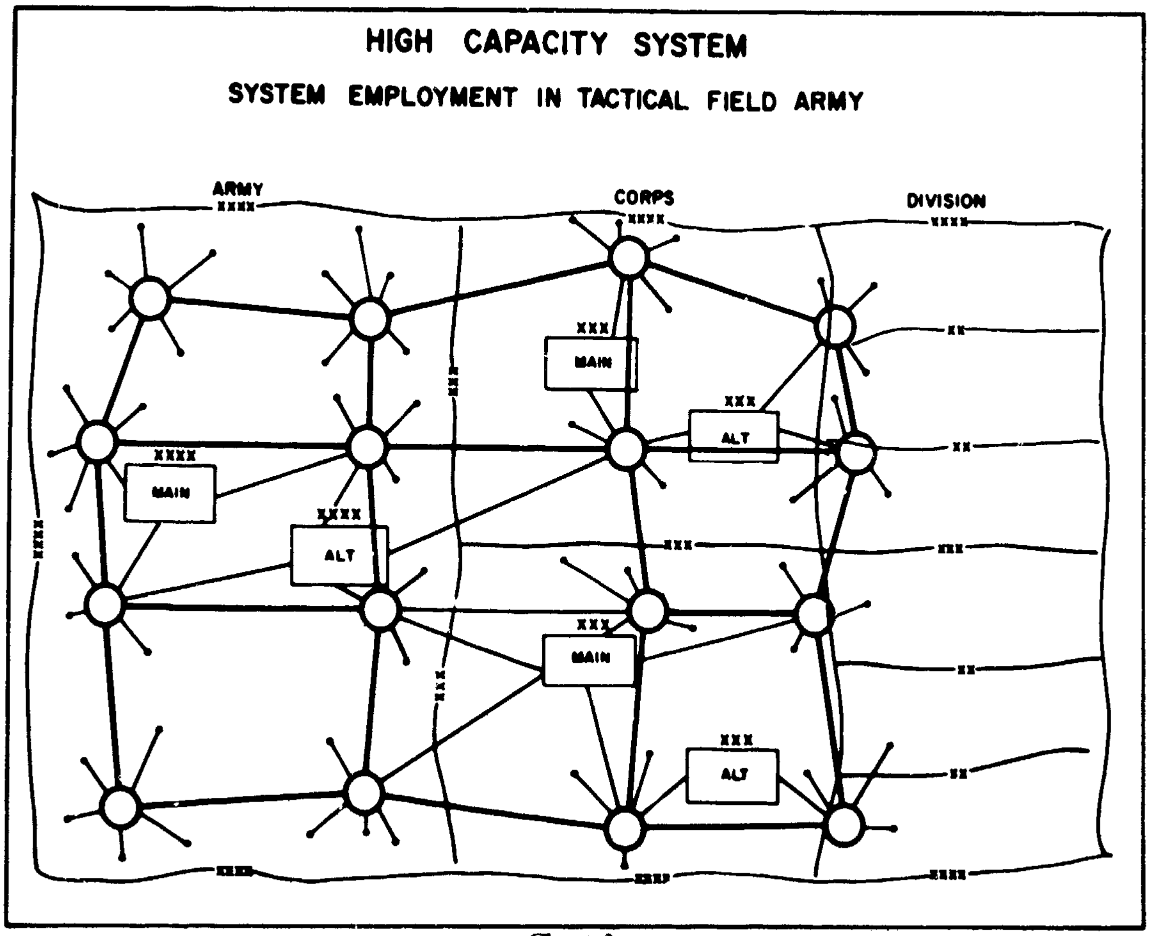

Chart 3

What can happen when A calls B?

He can get through

He cannot get through

He has to wait a long time

His message is distorted

He gets interrupted

Etc.

What we will be aiming at, during the rest of my talk is an answer to the question:

So what?

If he gets through

If he doesn't

Etc.

We are going to proceed along the following lines:

1. Describe the users - who they are and where they are

2. Define the *requirement* to communicate

3. Translate user requirements to network requirements

4. Show how equipment alternatives enter in the analysis

5. Discuss a simulation for this network

6. Make a connection between communications performance and military performance

However, we are going to start by showing you how to avoid the problems in our story of "A calling B". The way to avoid it is to give A and B a private line.

Since the channel space in the Army's communication system is limited, (Chart 4) whatever channels exist are shared by the users, and the system is called a common-user system. However, certain users have more critical communications requirements than others perhaps so important that the success of communications cannot be left to change. In these cases, some of the channel space is set aside for their exclusive use. This eliminates competitors from these channels and the owners are referred to as "sole users". This certainly improves *their* communications, but to the detriment of all the common-users since some of their channel capacity is lost to them. Chart 4 shows some typical sole users associated with the main Army Headquarters.

Chart 5 is a sort of schematic showing the sole user circuits passing through the signal centers as if they were not there. The signal centers are square block instead of round as previously used. As you can see, the more sole user channels you permit, the fewer left for everyone else to use. This is an interesting trade-off problem in military effectiveness. Look at signal center No. 6, for example. Three quarters of the channels from there to signal

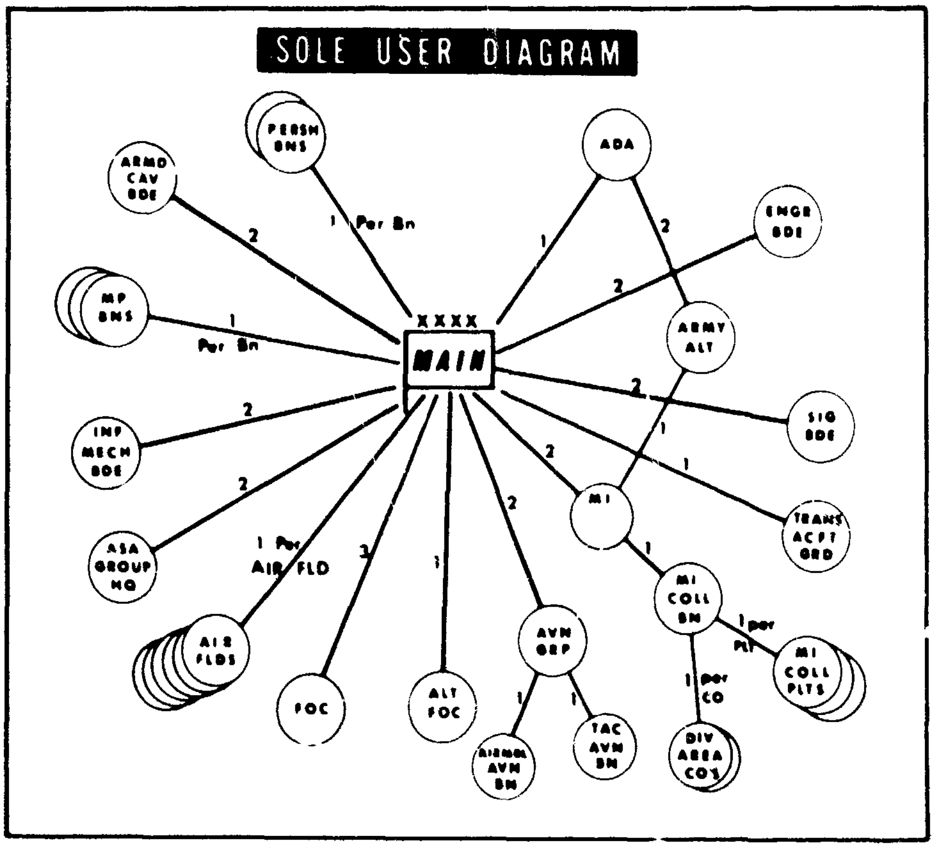

Chart 4

center No. 5 have been consumed by sole user patch-throughs. Is that good or bad? We shall see how to get an answer to this question shortly.

Let us get more specific about a common-user communications system that we want to analyze. Some of the first questions that must be answered are: who are the communicators and where are they with respect to each other? Consider this example of an Army of two Corps, each Corps with three divisions. From the command point of view, this Chart 6 identifies the main headquarters units and their relative locations.

Down within the divisions on the right are the multichannel command and control systems which include many common user channels. Brigade encampments like the one we saw earlier are included in these networks.

Command and control for Army Corps and division is shown. This type of multichannel system will be troposcatter. Note that we now have a communications capability from brigade all the way up to Army Headquarters through a common-user system.

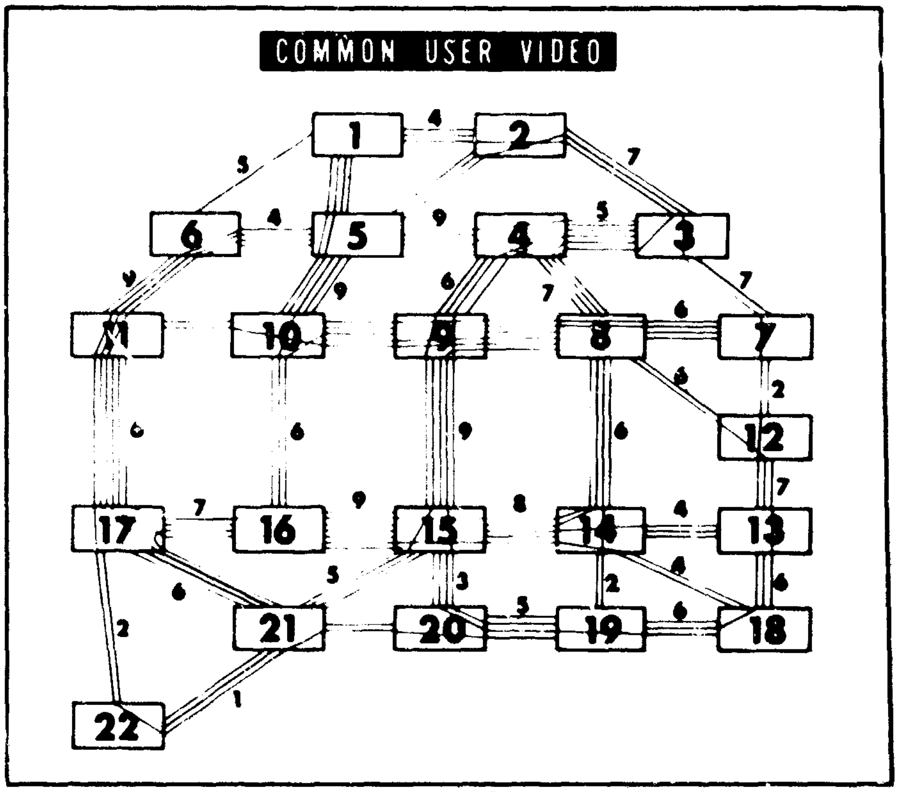

Chart 5

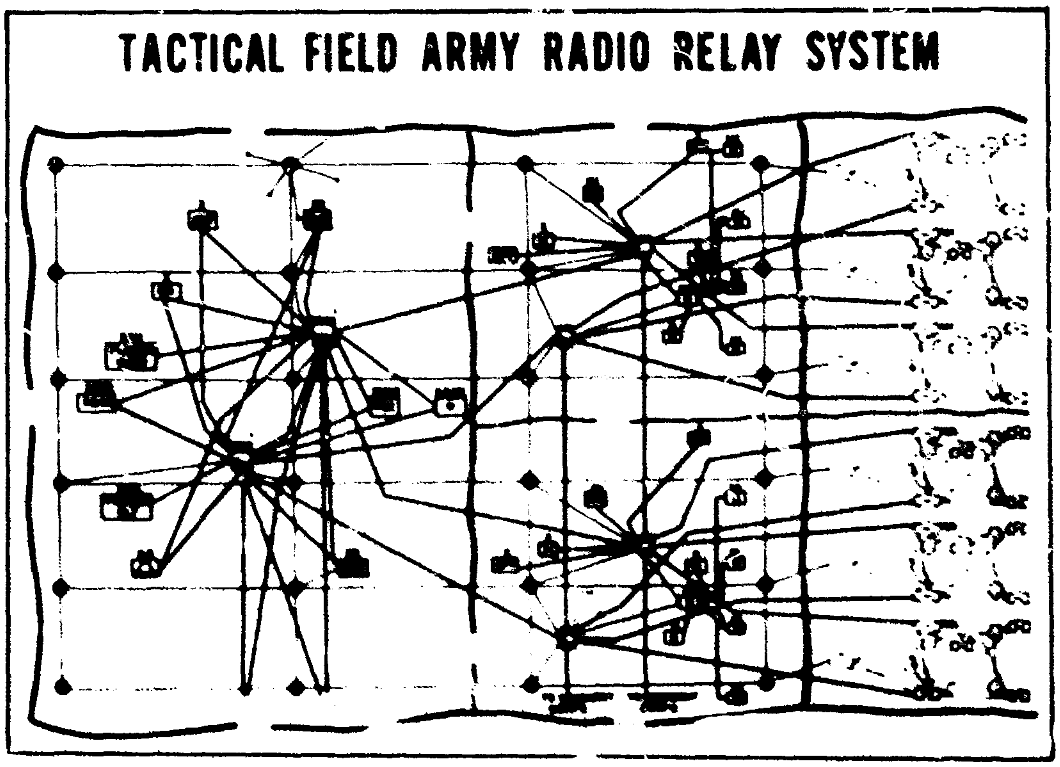

Chart 6

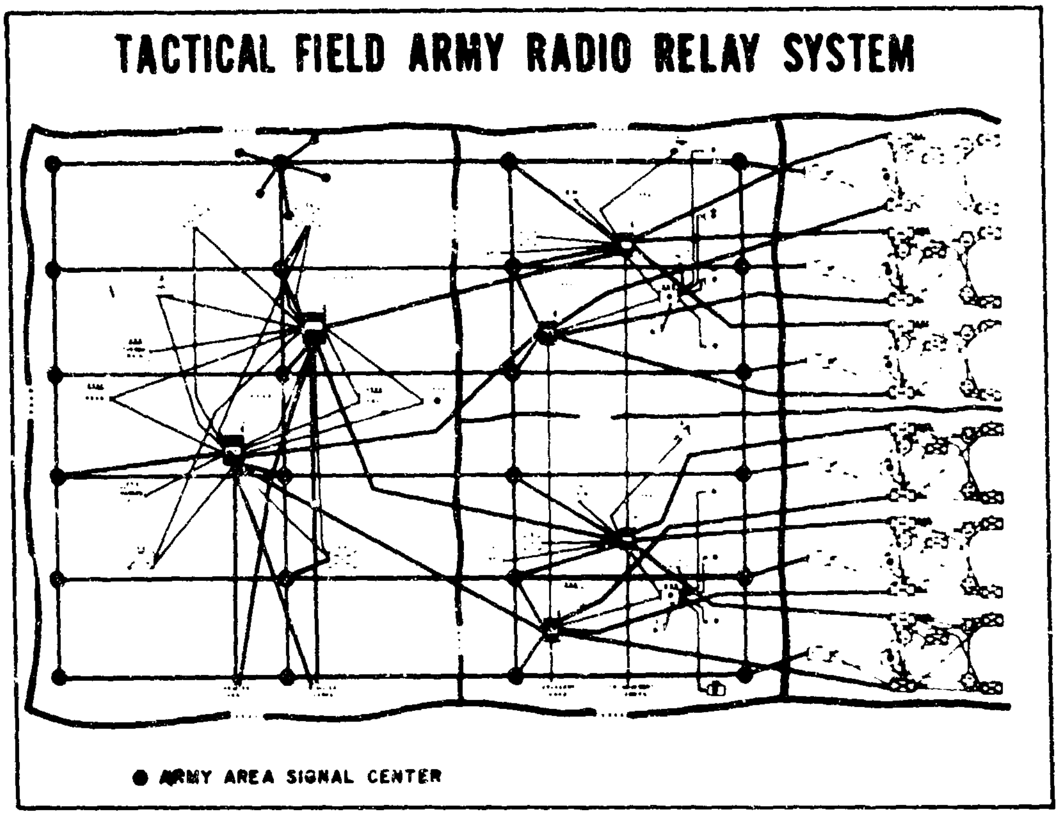

Chart 7

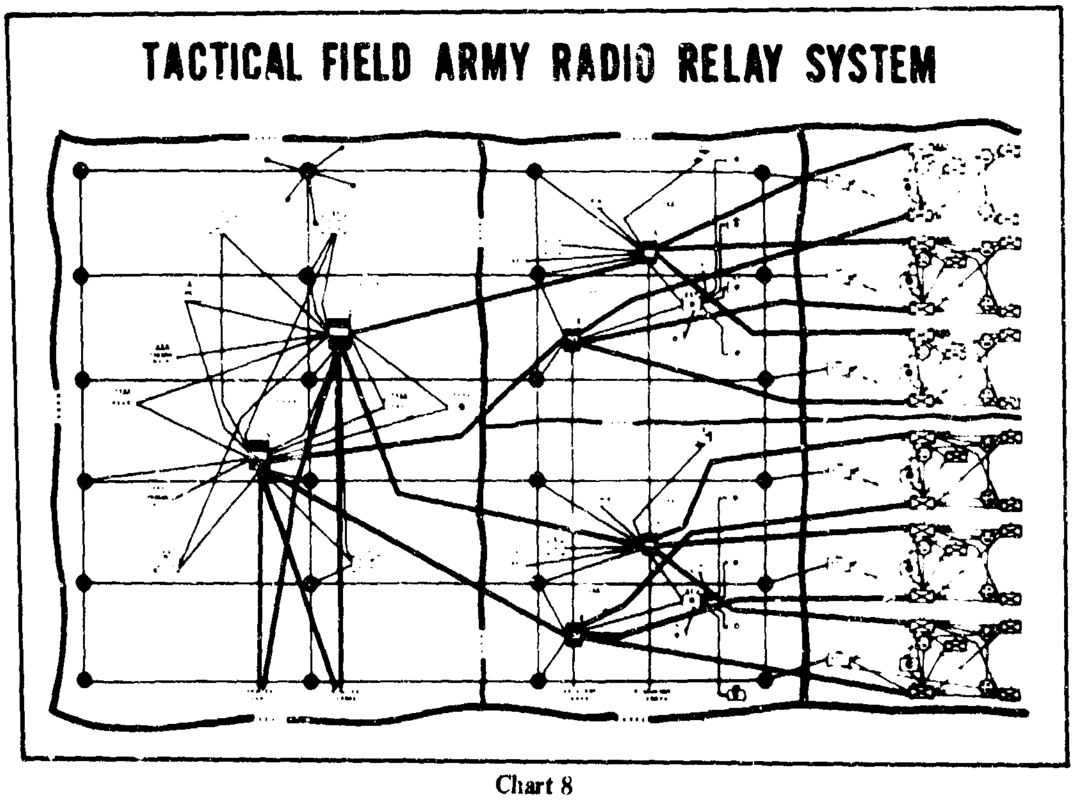

Chart 8

Not all the units of a field army belong to the neat hierarchy of Army-Corps-Division-Brigade-etc. There are other combat units like Corps Artillery () and support units like FASCOM or the aviation group (), or the flight operations center (). These military units join the overall network by means of the lines shown. Of course, they have access to the same channels in the troposcatter system as other people do. And vice versa. In other words, the systems are commonly used.

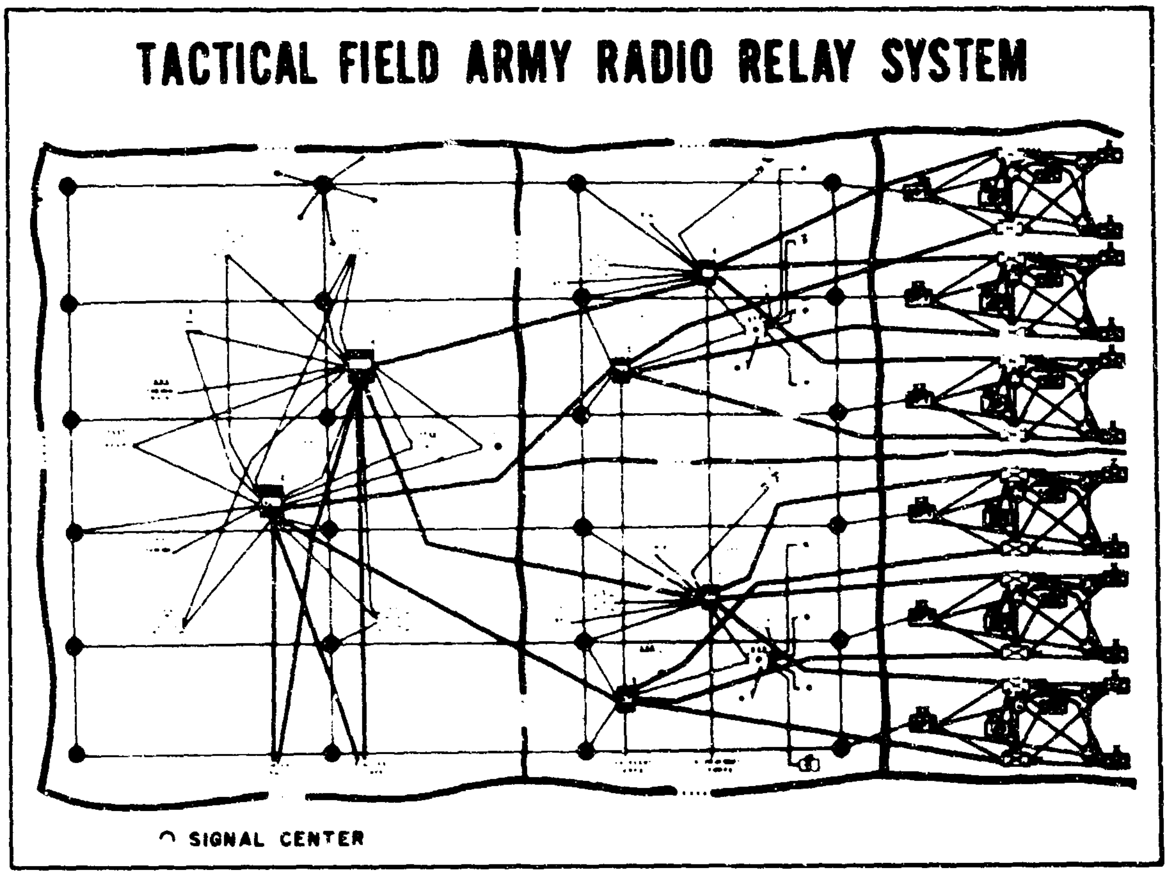

Chart 9

Finally, the mainstay and catchall for communications other than the command system is shown and referred to as the area system. As indicated, it can be used as an alternate for the command system. It is the only means of communications for some military units now shown. Taken together each represents a somewhat complex network of communications in which the channel resources are divided between sole-user circuits and common-user circuits.

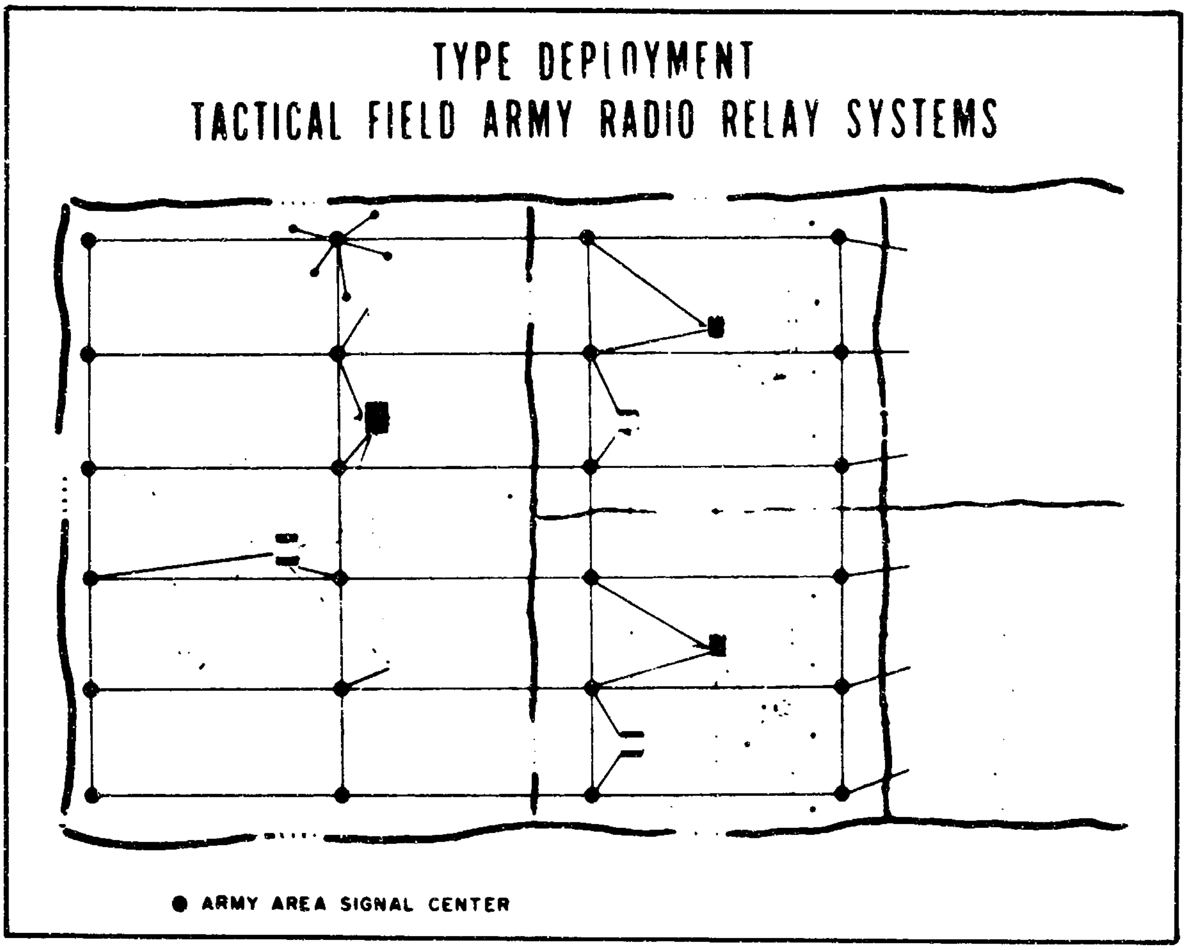

Chart 10

We would like to consider, now, how to analyze this common-user network. We want to answer some very basic questions about it. First, is the common-user network adequate? Second, given two or more alternatives, decide which one is better?

Let's begin an analysis and do it in terms of the Army network we were just looking at. The very first step is to identify every user of the system. For realism, each unit is located on a map using a typical deployment. The "Field Unit Deck" shown on chart 11 is a list of all identified military units using the system with their location.

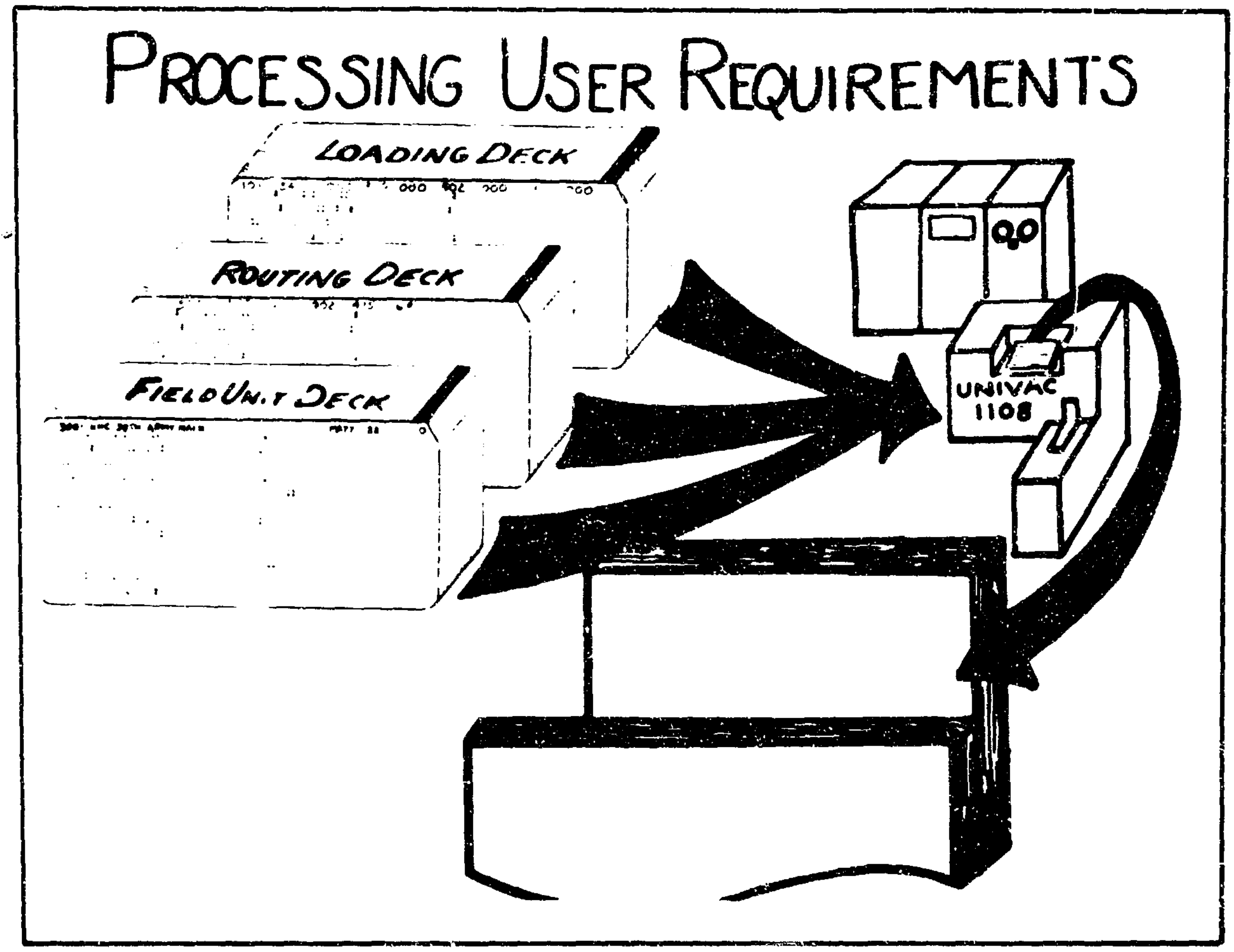

Chart 11

After the users are identified, their doctrinal requirements to communicate are stated. For example, which units in the troop list are *required* to communicate with Corps Artillery?, with each element of FASCOM?, with division headquarters?

Not only that, but how much traffic ordinarily transpires between these units during the conduct of battle? This information is correlated to the troop deck by the routing and loading deck.

All these requirements are referred to as "user requirements". Their importance cannot be over emphasized. If you leave anyone out, the impact on the use of the system will be excluded, and this may invalidate the analysis. For example, the other users will not have to compete against his traffic. This would be unrealistic. Another point is that the declared quantity of traffic for each user has an enormous impact upon how well a given system or channel resource will satisfy the requirement for prompt communications. The same considerations apply to the "need lines" contained in the Routing Deck.

The user requirements represent the load on the system being analyzed. If the load is not correct, the analysis suffers. The so called "correct" load includes the contribution to traffic caused by the nature of the military forces, their tactics, doctrine and items of material appropriate to the time frame being considered.

Once the user requirements data has been computerized, we can summarize the requirements as you see here (Chart 12). For each unit in the Army we can print out the traffic to all other units for which there is a doctrinal requirement to communicate. This covers telephone, teletype, and data. Also included are the location of these other units and their access information like node and loop group descriptions.

From-To User Requirements

FROM	TYPE	SER.	NAME	COORD.	GROSS CHAN. RQMTS. TTY	TP	ADL	NODE	LPGP
	101	3001	HQ 30TH ARMY MAIN	MA7722				97	776
TO									
	451	1000	HHB 43RD ADA BDE 30TH ARMY	MA7226	.044	1.190	-.000	103	808
	331	1461	HQ + SP TROOP 30TH FASCOM	MA4835	.040	2.360	-.000	100	800
	452	922	HHC 30TH ENG BDE 30TH ARMY	MA5134	.124	1.450	.000	2	432
	453	910	HHC 20TH SIG BRIGADE 30TH ARMY	MA4750	.044	.200	.000	3	450
	622	1032	HHC 236TH MIL INTEL BN 30TH ARMY	MA7624	.024	.600	.000	97	799
	554	1145	HHD 30TH CHEMICAL GRP 30TH ARMY	MA7333	.024	.210	.000	15	219
	555	1346	140TH AVIATION CO 30TH ARMY	MA7042	.044	.210	.000	96	796
	102	3002	HQ 30TH ARMY ALT	MA6051	1.100	4.800	-.000	98	792
	103	3003	HQ 30TH ARMY REAR	MA4539	.040	.630	-.000	99	798
	201	1900	HQ 3RD CORPS MAIN	MA1063	5.300	6.730	.000	85	704
	201	5000	HQ 2ND CORPS MAIN	NA 430	5.300	6.730	.000	91	743
	202	1899	HQ 3RD CORPS ALTER	NA 573	.160	.310	.000	86	713
	202	4999	HQ 2ND CORPS ALTER	MA9336	.160	.310	.000	92	752
	306	1476	HQ ARMY ARTILLERY	MA7252	.044	1.190	.000	102	806
	540	920	HHD 22ND MP GRP 30TH FASCOM	MA5323	.000	.300	-.000	2	437
	902	1475	TECHNICAL INTELLIGENCE CTR	MV1179	.000	.060	.000	10	491
	602	1143	150TH AVIATION TRAFFIC CONTRL 30THA	MA7529	.000	1.000	.000	104	811
	450	2501	HHT TRP 203 ARMD CAV REGIMENT	MA3808	.044	1.130	.000	105	813
	720	2502	AIR CAV TROOP 203RD A/C REGT	MA3590	.044	1.130	-.000	105	814
	720	2552	204TH AIR CAVALRY 204TH REGT	MA9178	.044	1.130	-.000	89	723
	720	5332	202ND AIR CAV 202ND ARMD CAVALRY	MA8940	.044	1.130	-.000	95	759
	421	2601	HHC 314 SEP INF BDE (MECH)	MA9056	.044	1.130	-.000	88	720
	421	5352	HHC 313TH MECH BRIGADE	NA 7 6	.044	1.130	-.000	94	758
	553	1241	HHC 26TH ASA GROUP 30TH ARMY	MA7624	.044	.480	-.000	97	787

FROM	TYPE	SER.	NAME	COORD.	GROSS CHAN. RQMTS. TTY	TP	ADL	NODE	LPGP
	102	3002	HQ 30TH ARMY ALT	MA6051				98	792
TO									
	101	3001	HQ 30TH ARMY MAIN	MA7722	1.200	2.290	-.000	97	776
	103	3003	HQ 30TH ARMY REAR	MA4539	.012	.310	-.000	99	798
	201	1900	HQ 3RD CORPS MAIN	MA1063	.040	.190	.000	85	704
	201	5000	HQ 2ND CORPS MAIN	NA 430	.040	.190	.000	91	743
	202	1899	HQ 3RD CORPS ALTER	NA 573	.080	1.020	-.000	86	713
	202	4999	HQ 2ND CORPS ALTER	MA9336	.080	1.020	-.000	92	752
	306	1476	HQ ARMY ARTILLERY	MA7252	.028	.310	-.000	102	806

Chart 12

It's time to state some of the conditions for our analysis (Chart 13). The nodes that service our Army must be interconnected in some manner. Suppose a rectangular pattern is assumed. The interconnections are multichannel radio links. The topology and number of channels can be the variables to be analyzed. We must declare also the rules pertaining to the establishment of sole user circuits. It may be said that traffic between two users in excess of a certain amount entitles those individuals to a sole user circuit. The routing doctrine is required, i.e., when A calls B. How is the path selected through the network. Likewise, certain equipment characteristics may be under consideration, like operation time for a circuit switch, or switchboard. These can also be included in the analysis which is starting to become complicated. It's time to say that all the things just mentioned are simulated in a computerized representation of the network. The simulation will be discussed in some detail, later. For now, we shall see what it does.

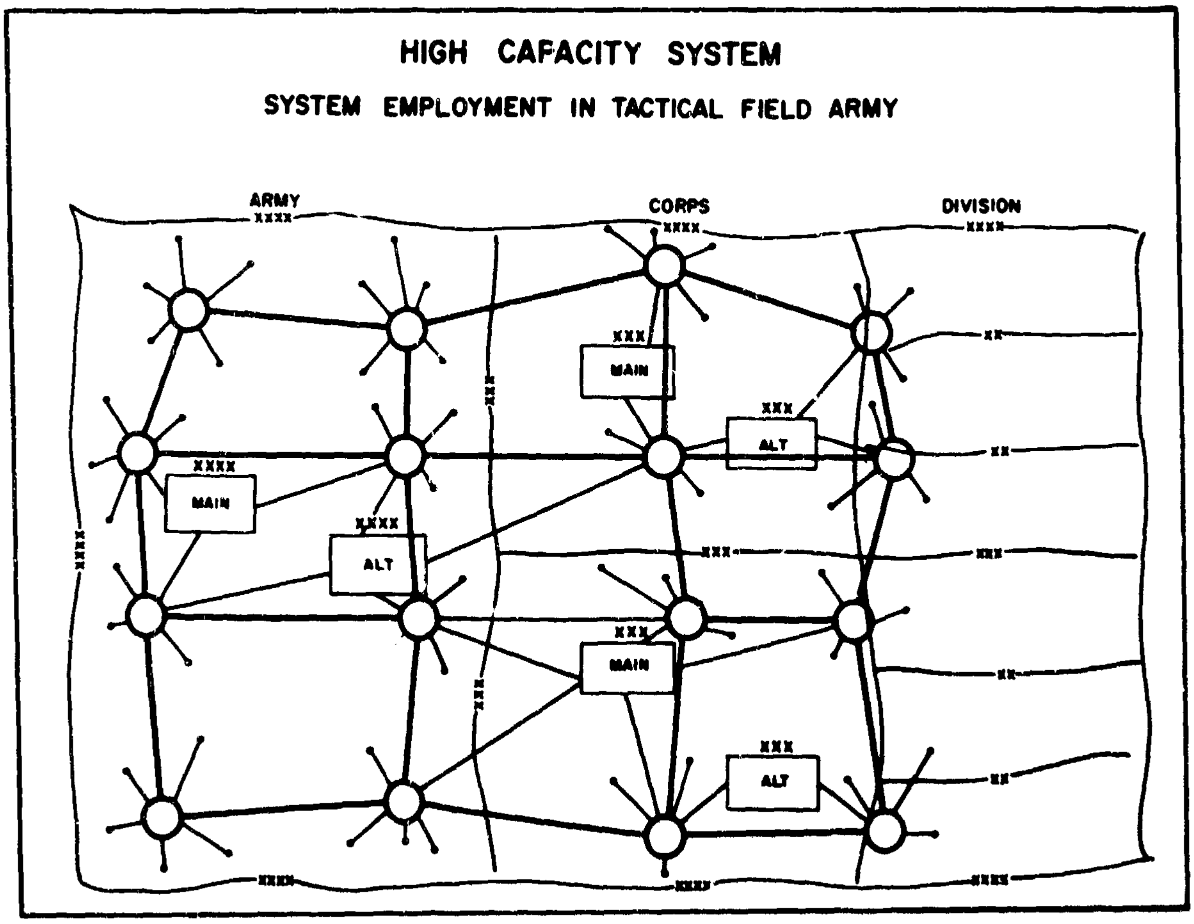

Chart 13

After the computerized simulation has digested all the facts, it starts to come up with some information on the system operation. It says for the users we have selected, where we have located them having the user requirements we declared, for the number of nodes we chose, with the link arrangement as indicated, for the number of channels we provided, using a certain routing doctrine, etc., the number of channels required for traffic looks like this. The numbers represent units of traffic. Note that because of patch through circuits belonging to certain sole users, the system behaves as if there are links which are not really there. Only the vertical and horizontal links are real, the diagonal links are functional, i.e., the system behaves that way because of the sole user patches. Emphasis is on which are functional and which are real, and point out that traffic in functional links is really passing through nodes. Grade of service equals .01 percent. There is *emphasis* if grade of service changes, channel requirements change, and any other inputs have impact upon channel requirements. Then, this is a summary of data, teletype, and telephone. Although not shown here, a companion analysis indicates whether or not this traffic will actually fit into the proposed system insofar as capacity is concerned.

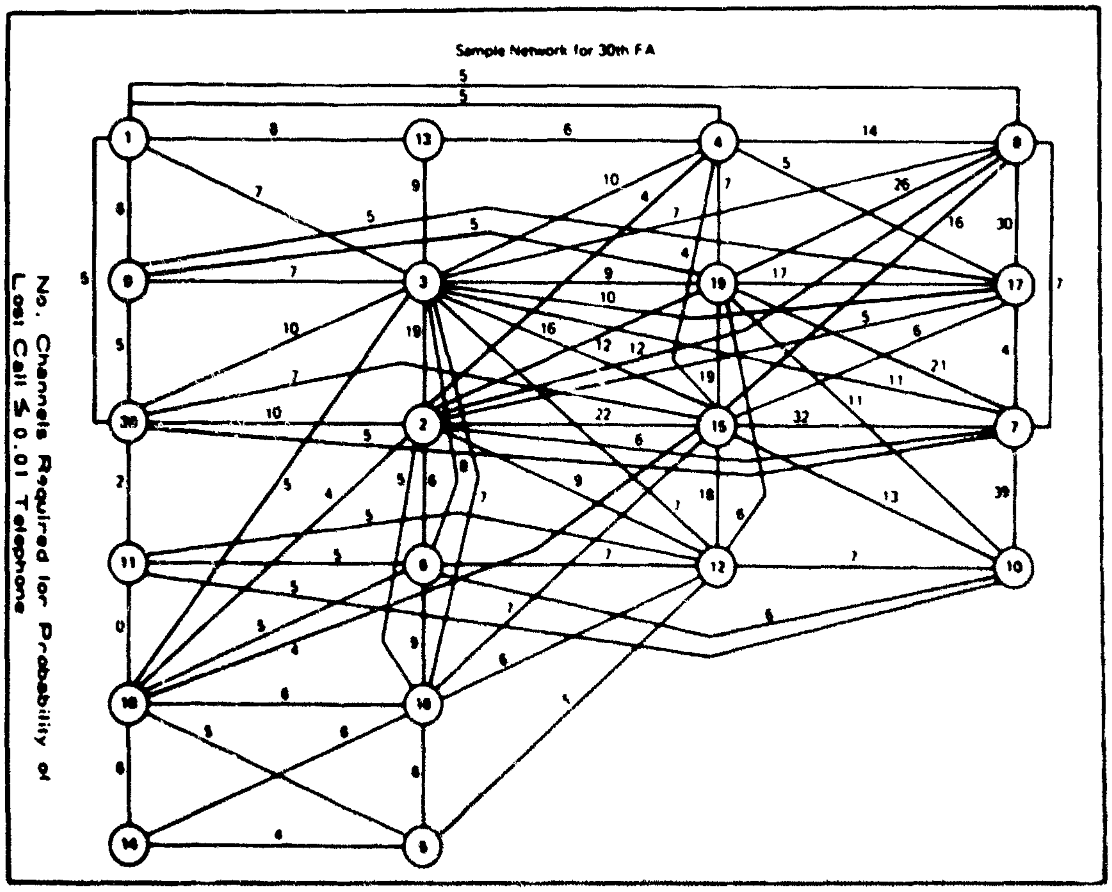

Chart 14

By means of the foregoing computerized analysis we can have the following kind of information (Chart 15). It is really the result of a bookkeeping account of where messages went to and come from. This is a summary of inter- and intranode traffic in the categories of teletype, telephone, and data. Some useful information on system utilization comes out of this; for example, is this very heavy or very light traffic?

FROM	TO	TTY	TP	ADL
1	1	.000	6.590	1.000
1	2	.040	.120	.000
1	3	.060	4.096	1.000
1	4	.000	2.500	.000
1	8	.000	2.560	.000
1	9	.000	3.000	1.000
1	12	.020	.130	.000
1	13	.060	7.723	1.000
1	15	.220	.073	.000
1	17	.000	.360	.000
1	20	.001	3.213	.000
TOTAL		.401	30.365	4.000
2	1	.036	.260	.000
2	2	2.392	39.741	.000
2	3	2.066	21.479	.000
2	4	.118	2.950	.000
2	6	.400	4.000	.000
2	7	.052	2.866	.000
2	8	2.412	9.049	.000
2	10	.028	.460	.000
2	11	.000	.030	.000
2	12	.150	7.551	.000
2	15	2.022	26.832	.000
2	16	.040	2.193	.000
2	17	.228	2.453	.000
2	18	.090	1.120	.000
2	19	1.086	10.586	.000
2	20	.064	8.209	.000
TOTAL		11.784	139.811	.000
3	1	1.098	5.603	1.000
3	2	4.068	23.876	2.000
3	3	2.390	59.521	5.820
3	4	.876	6.643	.000
3	5	.000	1.013	.000

Node Traffic Summary

Chart 15

This is similar to the node traffic summary. It is for the links; this example is for teletype only. It is a cross section of what is flowing through the pipes. Link two carries traffic originating at four different nodes and ending at five other nodes. If Link two is jammed, this identifies the traffic which will not get through. You can identify the users by organization.

```
LINK  1 TRAFFIC DIRECTED FROM NODE  1 TO NODE 13
   NODE OF ORIGIN  TERMINUS NODE      TTY       TP          ADL
         1               13          2.000     .000        .000
         4                9          3.000     .000        .000
          *** TOTAL ***              5.000     .000        .000
LINK  1 TOTAL ******                 5.000     .000        .000
LINK  2 TRAFFIC DIRECTED FROM NODE  3 TO NODE  9
   NODE OF ORIGIN  TERMINUS NODE      TTY       TP          ADL
         1                3          5.000     .000        .000
         2                9          5.000     .000        .000
         3                9          3.000     .000        .000
         9               12          3.000     .000        .000
         9               15          5.000     .000        .000
         9               19          3.000     .000        .000
          *** TOTAL ***             24.000     .000        .000
LINK  2 TOTAL ******                24.000     .000        .000
LINK  3 TRAFFIC DIRECTED FROM NODE  2 TO NODE 20
   NODE OF ORIGIN  TERMINUS NODE      TTY       TP          ADL
         2               20          2.000     .000        .000
          *** TOTAL ***              2.000     .000        .000
LINK  3 TOTAL ******                 2.000     .000        .000
LINK  4 TRAFFIC DIRECTED FROM NODE  6 TO NODE 11
   NODE OF ORIGIN  TERMINUS NODE      TTY       TP          ADL
         6               11           .000     .000        .000
          *** TOTAL ***               .000     .000        .000
LINK  4 TOTAL ******                  .000     .000        .000
LINK  5 TRAFFIC DIRECTED FROM NODE 16 TO NODE 18
   NODE OF ORIGIN  TERMINUS NODE      TTY       TP          ADL
        16               18          2.000     .000        .000
          *** TOTAL ***              2.000     .000        .000
LINK  5 TOTAL ******                 2.000     .000        .000
LINK  6 TRAFFIC DIRECTED FROM NODE  5 TO NODE 14
   NODE OF ORIGIN  TERMINUS NODE      TTY       TP          ADL
         5               14           .000     .000        .000
          *** TOTAL ***               .000     .000        .000
LINK  6 TOTAL ******                  .000     .000        .000
LINK  7 TRAFFIC DIRECTED FROM NODE  4 TO NODE 13
   NODE OF ORIGIN  TERMINUS NODE      TTY       TP          ADL
         2                8          7.000     .000        .000
```

Link Traffic Summary

Chart 16

So far (Chart 17), the analysis hasn't included much in the way of technical details of the equipment. Since the locations of the users are known, the routes are known, the main system features are known, then the actual equipments can be considered. Chart 22 shows two routes possible between the aviation battalion and corps main; note that specific equipment nomenclatures are accounted for. The technical features and performance of these equipments can also be included in the computerized simulation.

For example, errors were introduced and there were time delays of switchboards, automatic switch and teletypewriter speed.

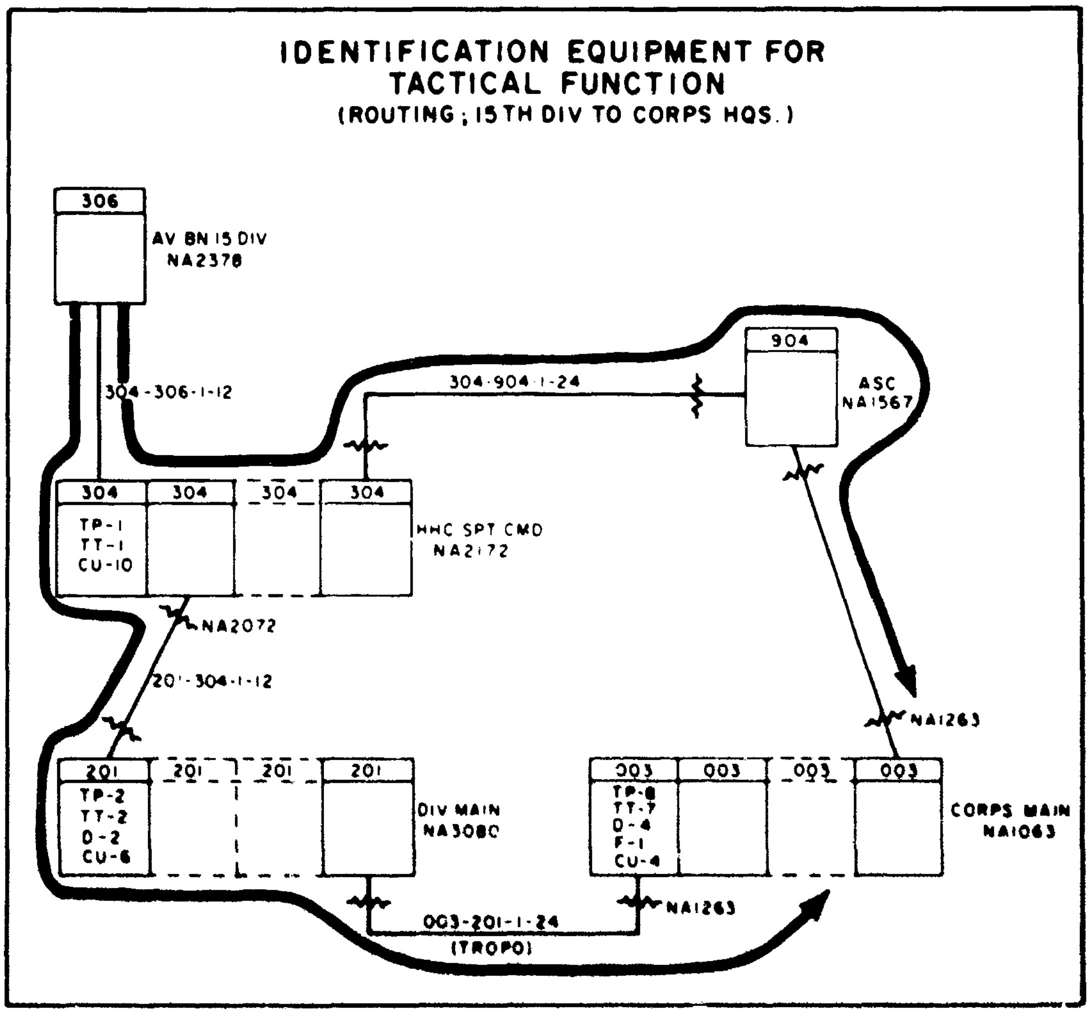

Chart 17

Chart 18 is how the computerized simulation is organized. The preprocessor accepts the inputs that are to be evaluated. This includes the characteristics and performance of the individual communications equipments as well as the connectivity of the system.

The dynamic simulator goes through the "nitty gritty" of running messages to and fro in accordance with the user requirements. In this way, the background traffic, or competition for tagged messages, is generated. Also, the tagged messages themselves try their luck in the dynamic simulator.

The post processor tells the results.

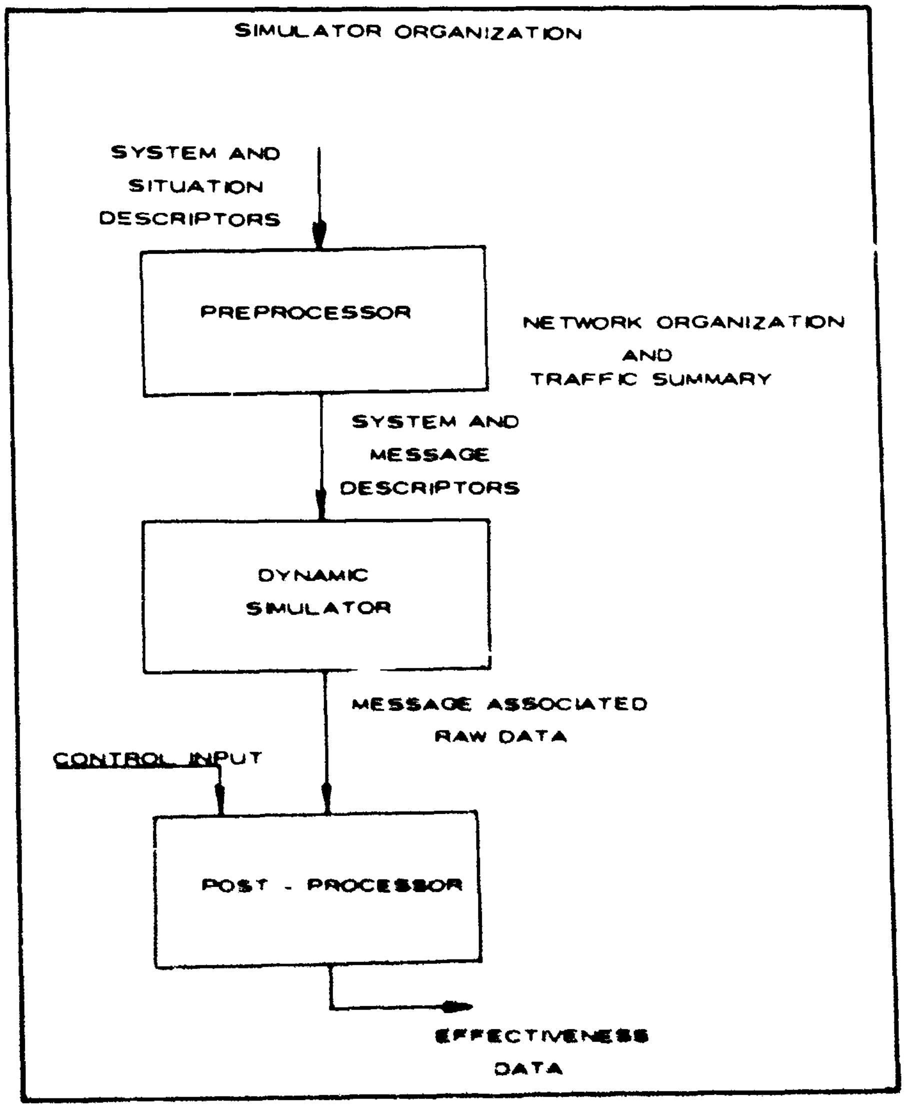

Chart 18

Chart 19 is a little more detail on the input to the simulation. The "basic network descriptors" include the number of channels provided in links. Stress factors mean jamming and damage if we want to consider those things in the analysis. Coming out of the preprocessor is a list of special outputs like queue lengths at certain nodes, or link utilization data. The message list includes all the background traffic and is based on the user requirements. Note that messages of special interest can be identified so that later on, their history can be printed out. These are so called tagged messages.

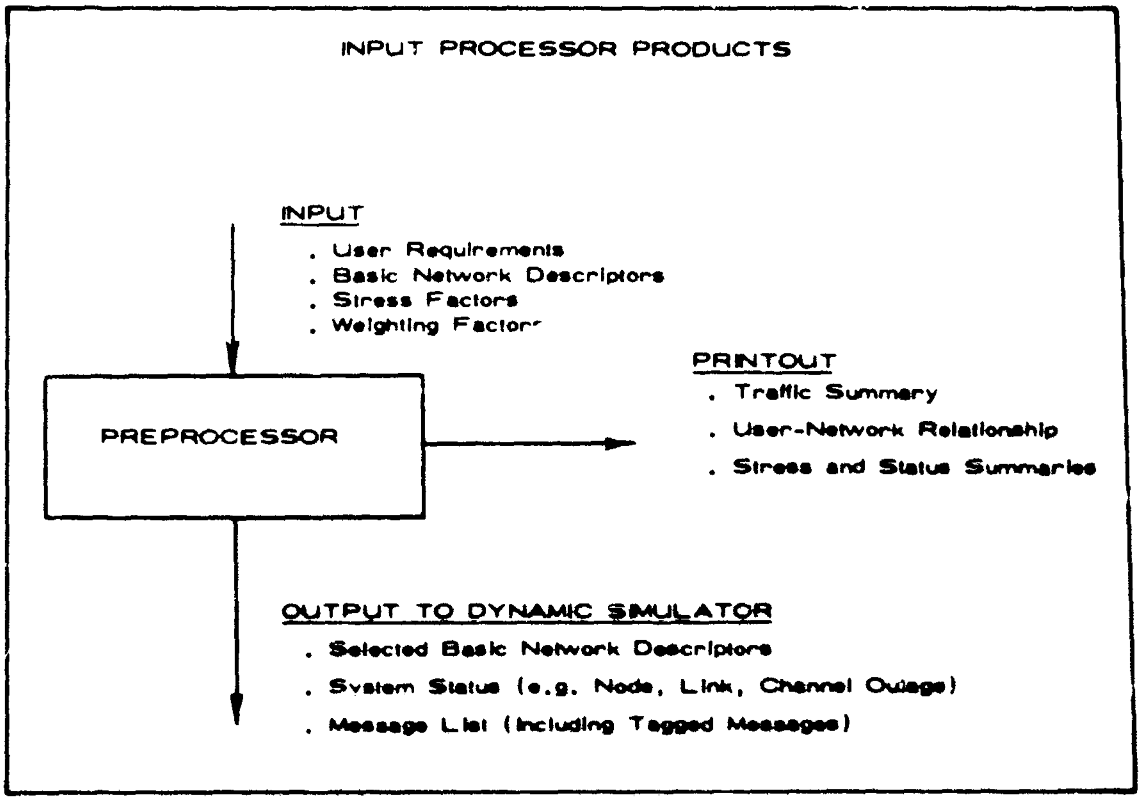

Chart 19

Now that the inputs are established (Chart 20) and we have some basis for conducting an analysis, the dynamic simulator takes over. It knows what to look for by prearrangement caused by the input processor. For example, it will keep track of queues at preselected nodes. It will also send messages, via the message generator, from all of the users to all the other users in accordance with the "user requirements." These messages will be carried over the network described by the preprocessor with the technical characteristics also contained therein. Certain message histories, the tagged messages, will be memorized.

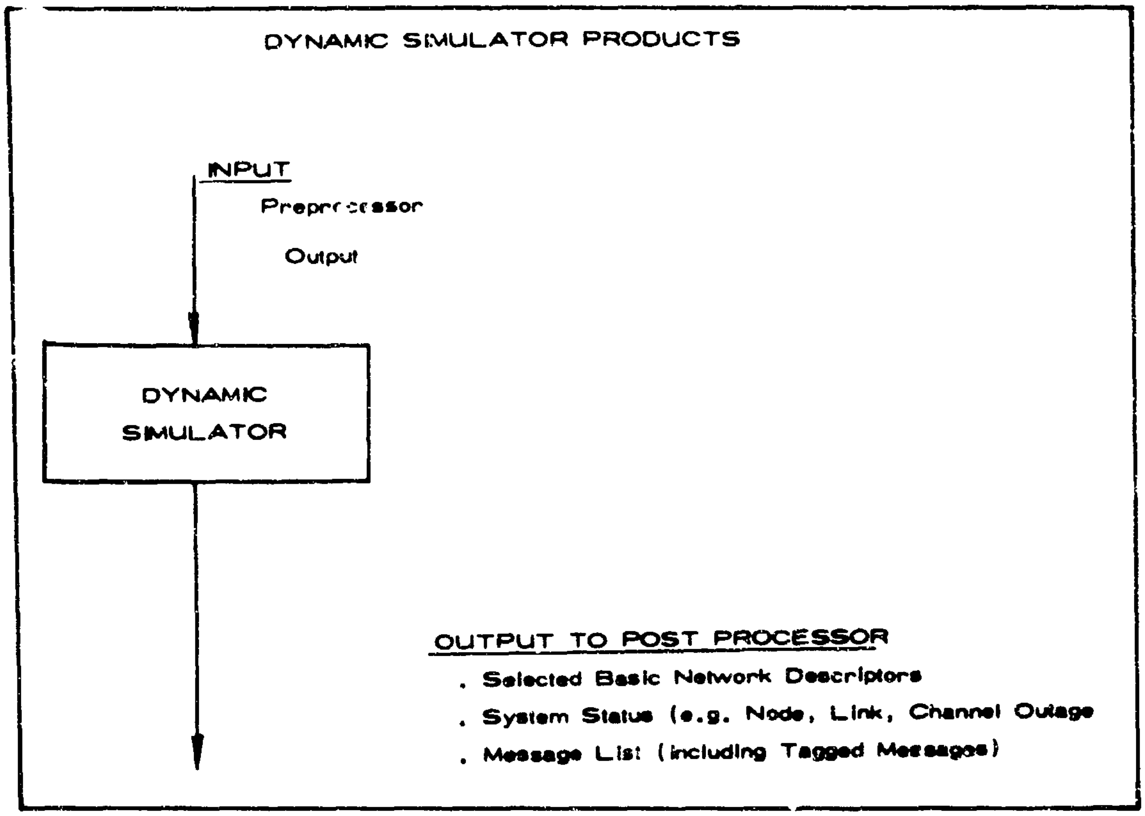

Chart 20

The post processor extracts desired information from the computer memory as shown in Chart 21. We can have single shot information from a Monte Carlo process, or we can get the mean and standard deviation. Some of the information is very special, like time delays, because this has an impact upon military operations. Another output of this type is total errors produced in a digital transmission. Finally, the post processor will do some simple arithmetic for you in compiling total effectiveness values by considering a number of individual but related effectiveness missions.

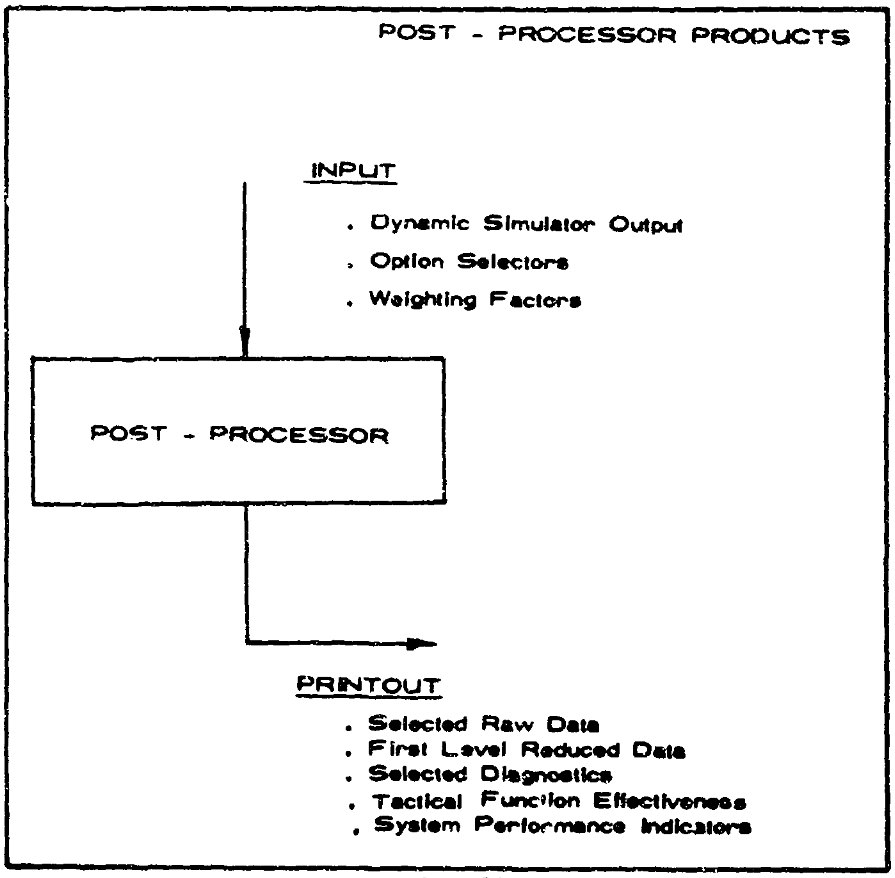

Chart 21

The whole purpose of our analysis is to show our customer some values of the communication system insofar as his work is concerned. (Chart 22). Our customer is the Army and their work is the conduct of war. From the Army commander's point of view, he may see what you are looking at. A confrontation of forces and some strategy involving high ground on the other side of the FEBA. There are offensive plans regarding this terrain (Chart 23). And plans for beyond that (Chart 24). The plans call for army units to accomplish objectives like seizing the indicated terrain. Some of the events that may occur are also indicated. There will be destruction of part of our communications system. There will be a river crossing, as indicated on the lower right corner. There will be close air support at objective f, etc. In each of these activities, like close air support, the communications system plays some part. We want to know more about this role of communication in order to make a judgment on the adequacy or worth of the communication system.

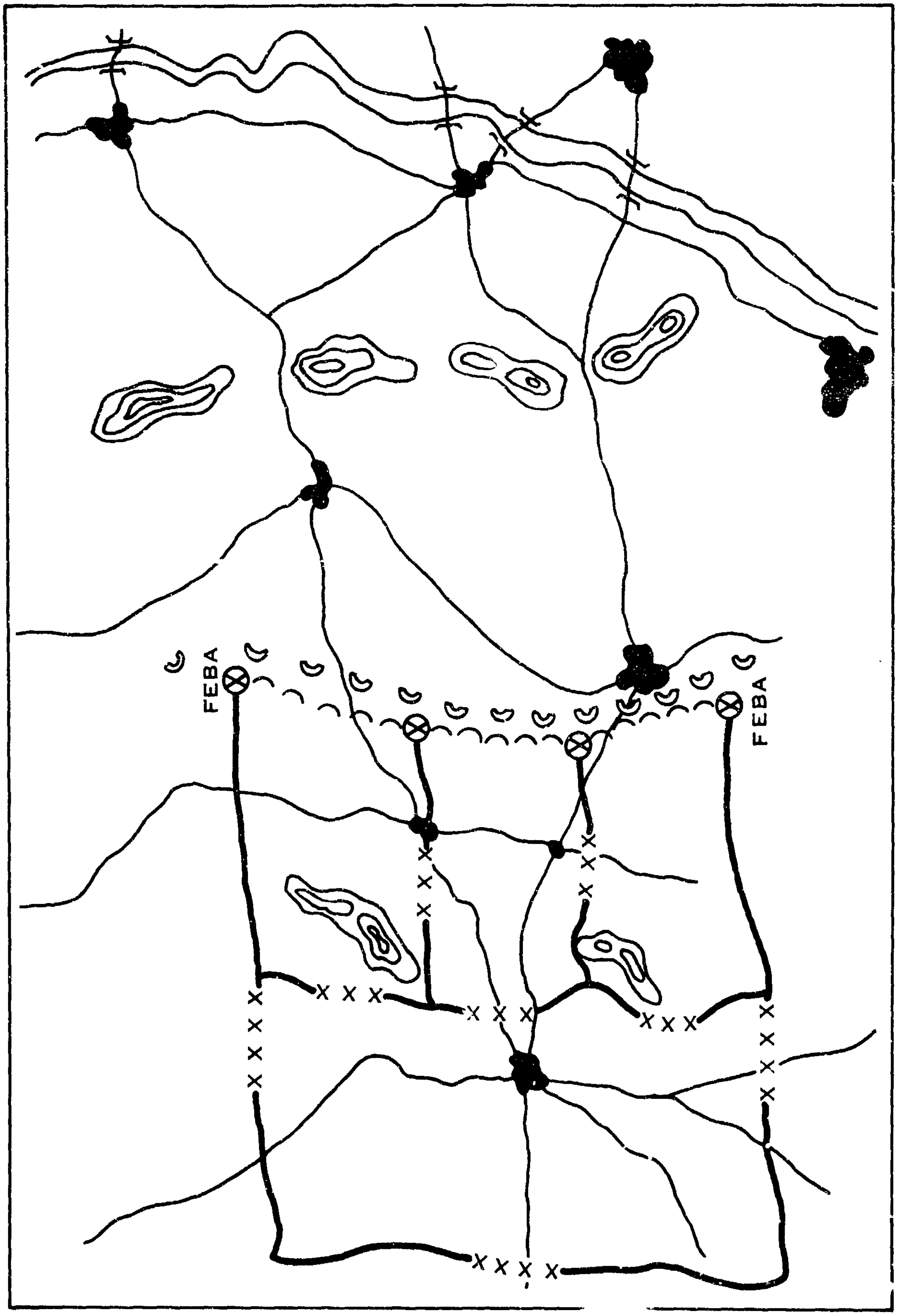

Chart 22

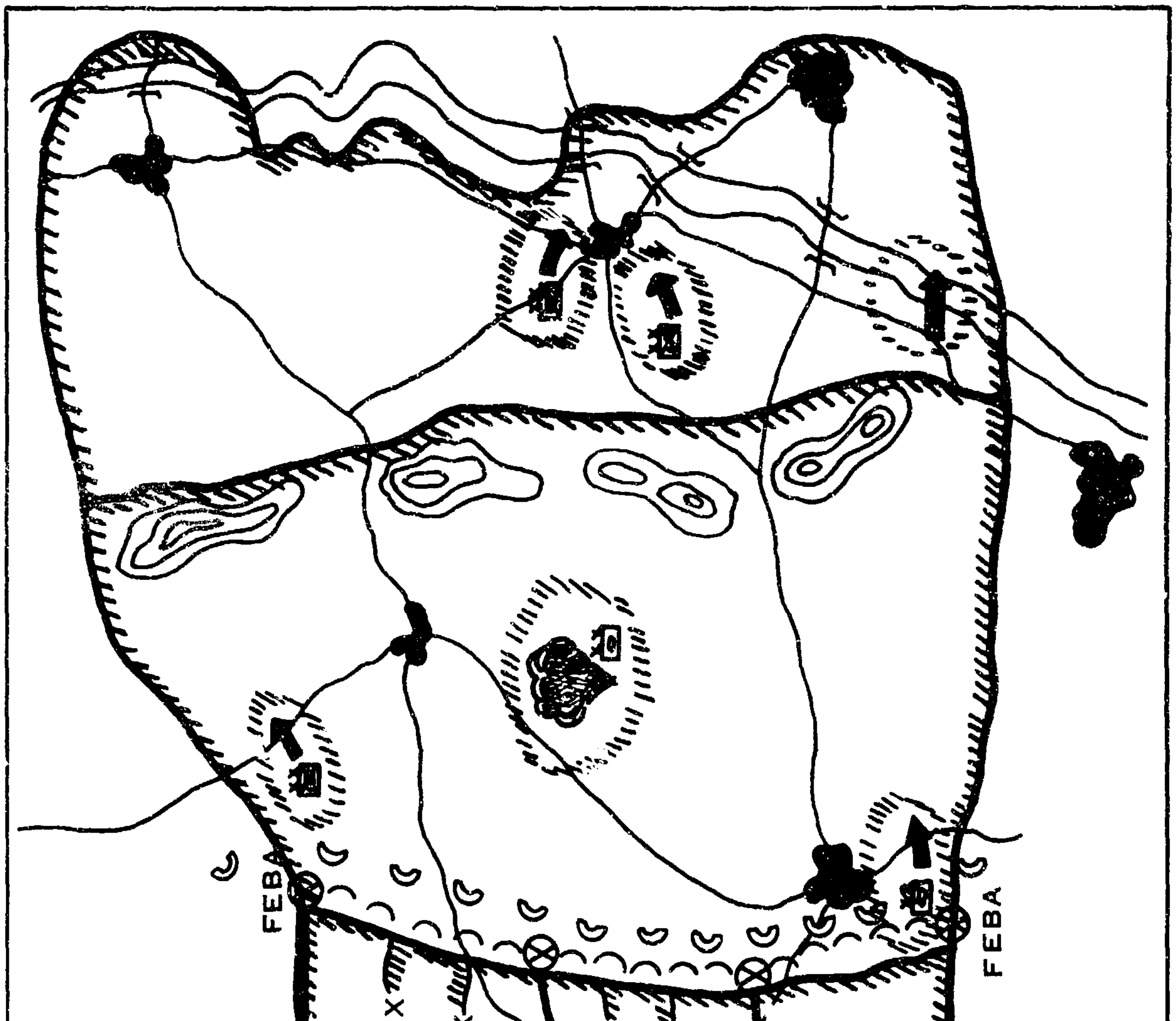

Chart 23

148 248 O - 69 - 13

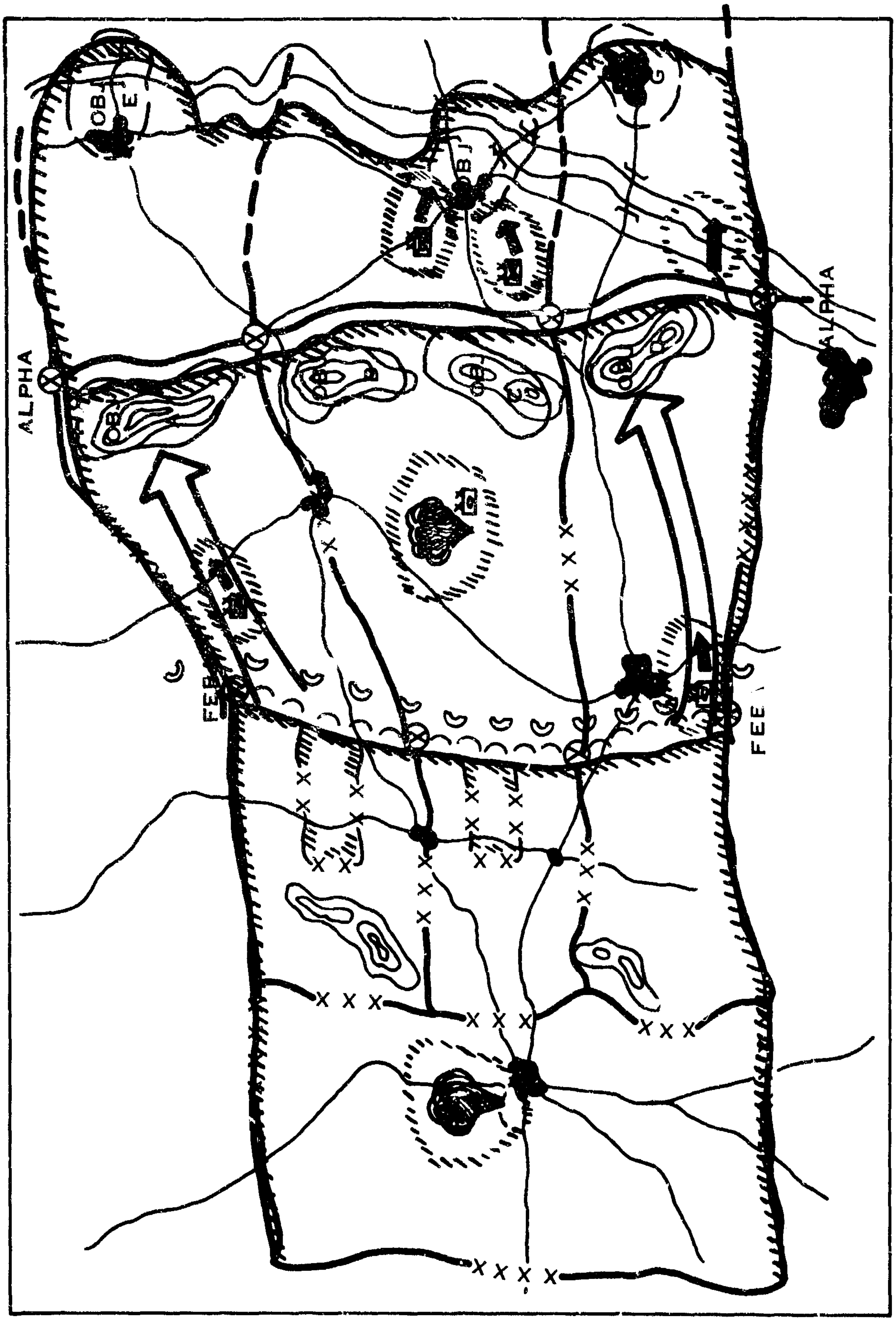

Chart 24

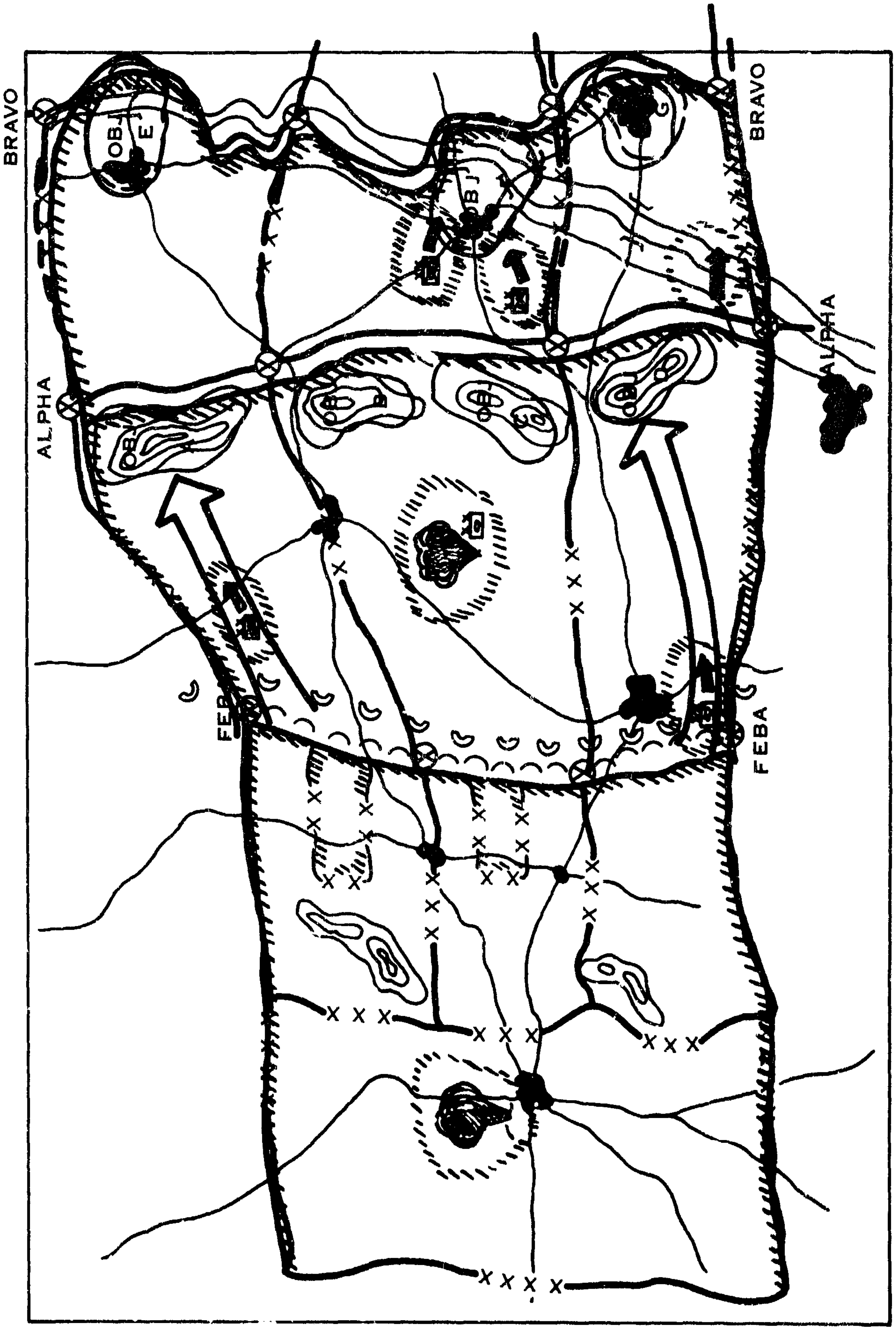

Chart 25

A military effectiveness analysis of a communications system can proceed along these lines (Chart 26). Tactical events or functions such as close air support, can be broken down into events which include the required communications. This is a highly simplified example. The important point is that *critical messages* are defined insofar as close air support is concerned. These messages transpire between specific users, namely some of the ones we have previously deployed on our maps. To determine military effectiveness, we simply ask our computerized simulation how will the system we are evaluating handle *these particular* messages between these specific parties. The answer will depend a great deal upon the "background" traffic, and upon how well these tagged messages go through the system in competition with everyone else's traffic.

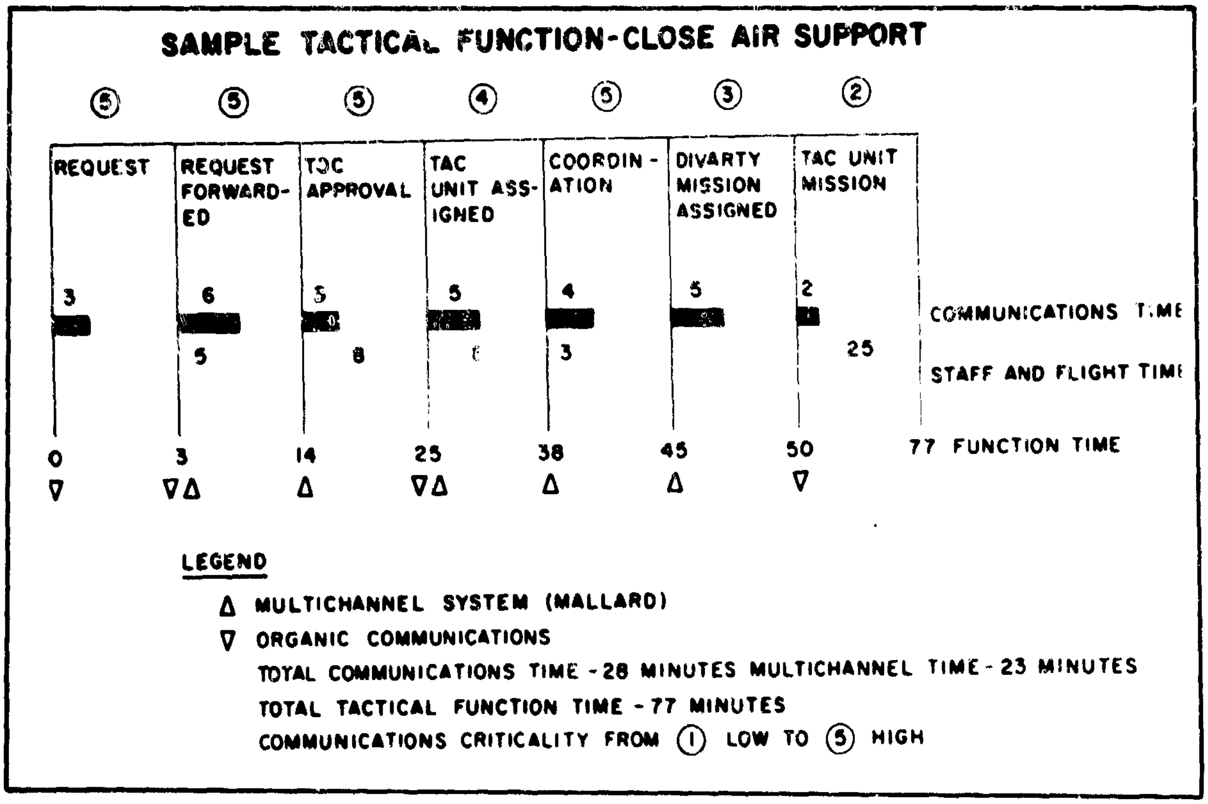

Chart 26

When we get an answer from the simulator, and this answer is introduced into the function breakdown, some military conclusion may result (Chart 27). For example, suppose this communication system introduced certain delays which held up or delayed performing close air support. There will be some impact, say on the force ratios at one of the objectives. The force ratios, of course, effect the military outcome.

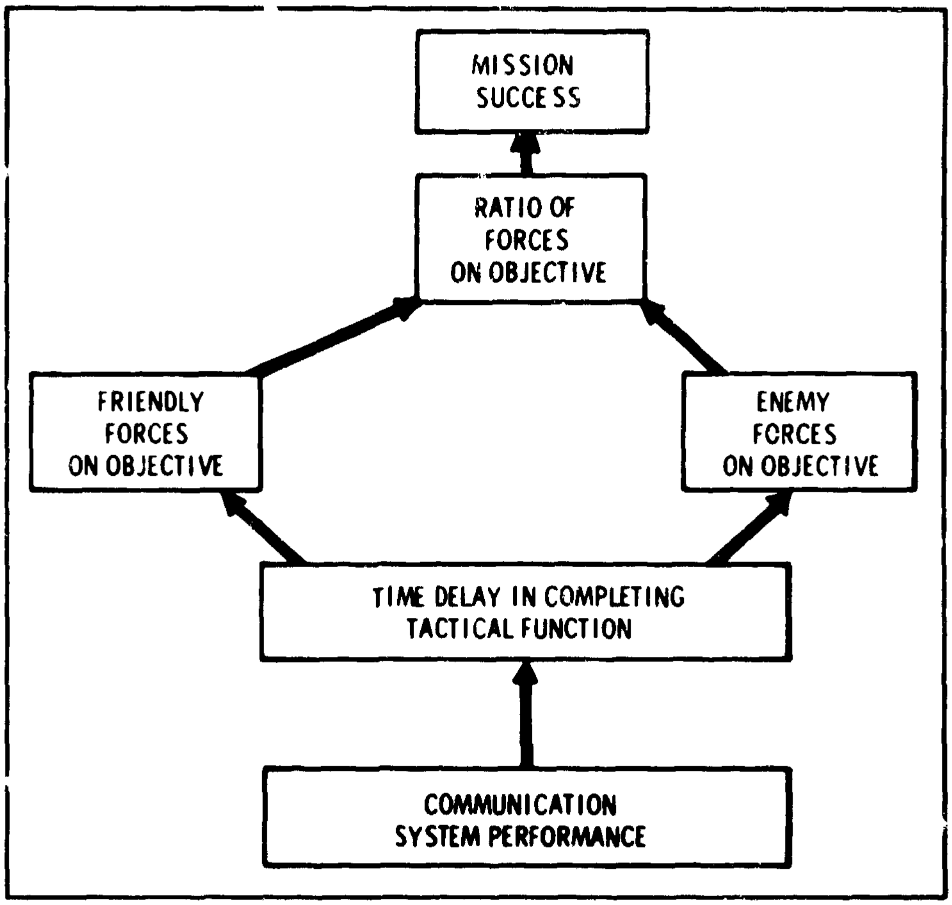

Chart 27

A variety of examples like this can introduce some military flavor into the evaluation of performance of a communications system. When analyses like the close air support function are broken down in detail and considered carefully (Chart 28), some very definite relationships are established between the success of the military event and unsatisfactory performance of the communication system. In a recent analysis at The Electronics Command, 28 examples like this one were derived for some of the military ingredients of Army warfare; an example is close air support. The usefulness of this graph lies principally in comparing two system alternatives. One may show up better than the other, or neither may be adequate, or there may not be a significant difference. Any of these answers are useful information.

348 348 O 69 14

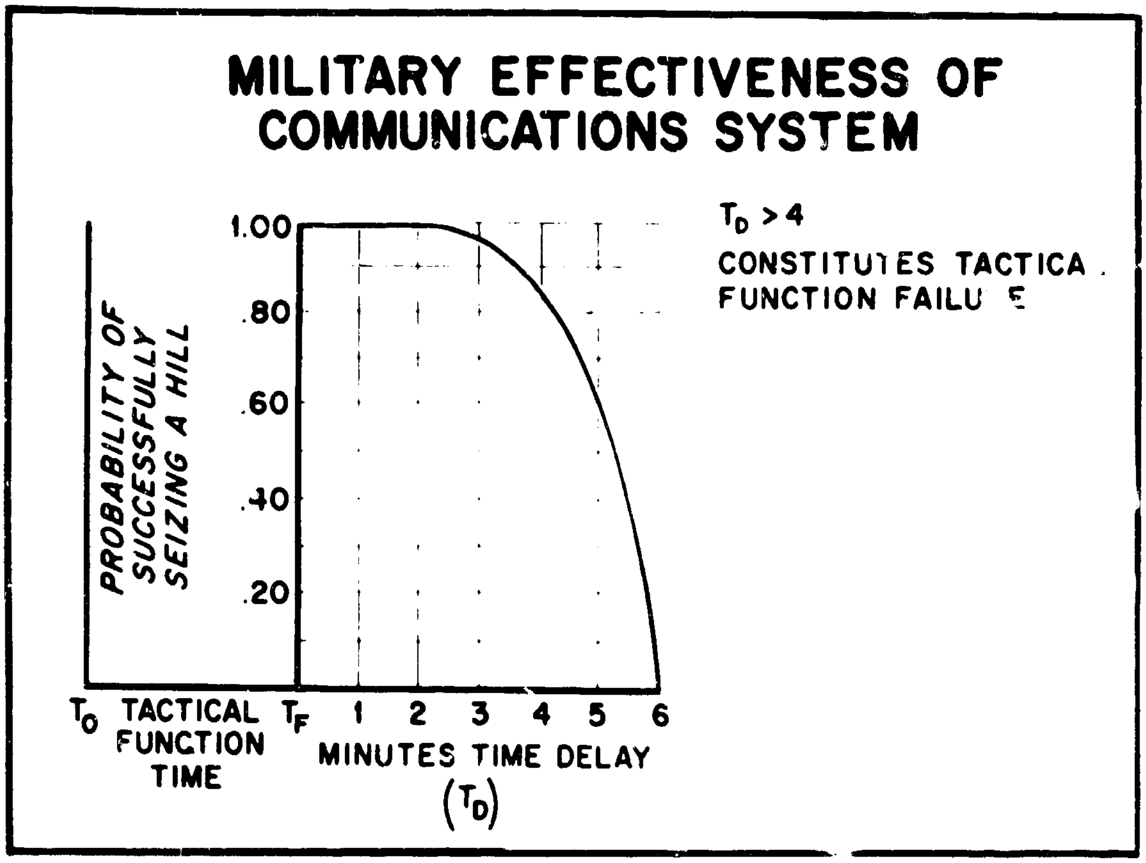

Chart 28

The alternatives are compared on the basis of one of the communication system features - in this case *time delay* - and that therefore no evaluation is included for other items of materiel - say a main battle tank.

Some exploration is underway at The Electronics Command to determine a suitable means of aggregating effectiveness information on tactical functions like close air support, movement of reserves, casualty evacuation, artillery support, logistic functions, river crossing, and bridging operations. These functions have great impact upon the effectiveness of maneuver brigades, and in turn upon their divisions, as you see on Chart 29. The importance of different military functions is being weighted along with the missions of different brigades in a given tactical situation. An overall army effectiveness determination is being attempted using this approach.

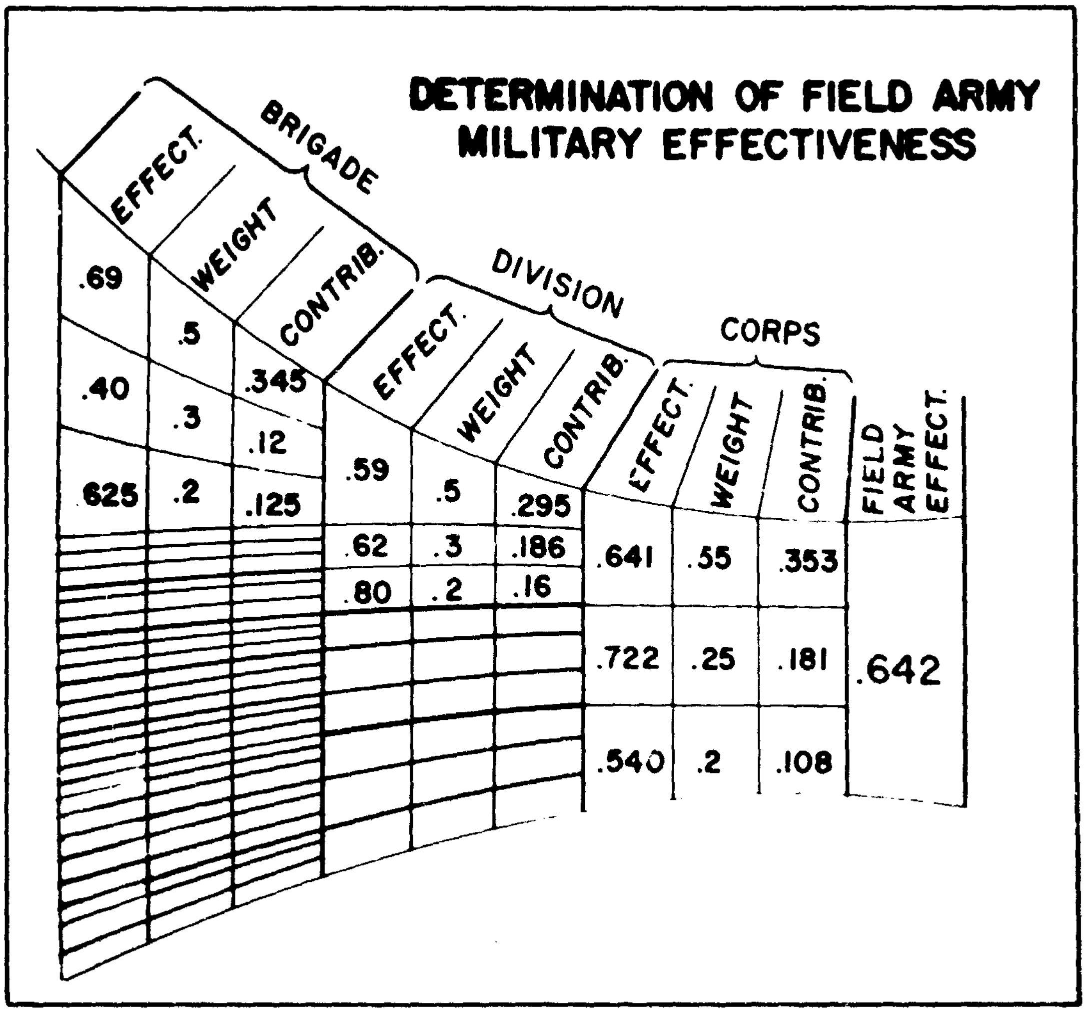

Chart 29

To summarize:

- Do it realistically by considering a specific force deployed to go into action.
- Determine who the communicators are and how much they talk.

- Do a paper installation of the equipment, or system being evaluated, for the force. This defines your network.

- Simulate the communication performance of the network.

- Assess the effectiveness in

  - Communication Terms

    1. Grade of service

    2. Delays

    3. Errors

    4. Queue lengths

  - Military Terms

    1. Impact upon tactical functions

       a. Artillery support

       b. Bridge errection

       c. Logistics

THE ORGANIZATIONAL STRUCTURE OF THE US ARMY AVIATION SYSTEMS COMMAND

Havard M. Bauer
Directorate of Systems and Cost Analysis
U.S. Army Aviation Systems Command
U. S. Army Materiel Command

The AVSCOM has undergone a major reorganization which became effective 1 October of this year. The new organization now known as the U.S. Army Aviation Systems Command evolved from the Brown Board Study along with changes incorporated by a management study team conducted over the past year at AVSCOM. This organization, as you will see, has been accepted at the AMC and the DA levels.

The Headquarters Commanding General and Deputy Commander/Chief of Staff supervises three Deputies. These Deputies are the Deputy for Research, Engineering and Data; Deputy for Acquisition; and the Deputy for Logistics. The Headquarters is composed of the Command Headquarters element along with those staff directorates and offices that are required to maintain such an activity. For example, the Command Judge Advocate, the Comptroller, Director of Programs, Installations and Services, etc. The Deputies for RED, Acquisition and Log wear two hats under the Systems Command structure. These are the associated deputies along with that of being the Commanding Officer of the respective Class II Activities under the Systems Command Headquarters.

U. S. ARMY AVIATION SYSTEMS COMMAND

COMMANDING GENERAL		
DEPUTY COMMANDING GENERAL, CHIEF OF STAFF		
USAAVSCOM RESEARCH, ENGINEERING & DATA ACTIVITY	USAAVSCOM ACQUISITION ACTIVITY	USAAVSCOM LOGISTICS SUPPORT ACTIVITY
COMMANDING OFFICER	COMMANDING OFFICER	COMMANDING OFFICER

Chart I

The interest is focused upon the Deputy for Research, Engineering and Data. As can be seen, the Deputy has two remote facilities; that of the AVLABS on the East Coast and the Army Test Activity, Edwards Air Force Base on the West Coast. The directorates shown on the chart are located at AVSCOM in St. Louis. As can be seen, the Directorate of Systems and Cost Analysis is one of the prime directorates under the Deputy for RED. This establishes the location and position of the directorate within the overall structure of the Systems Command.

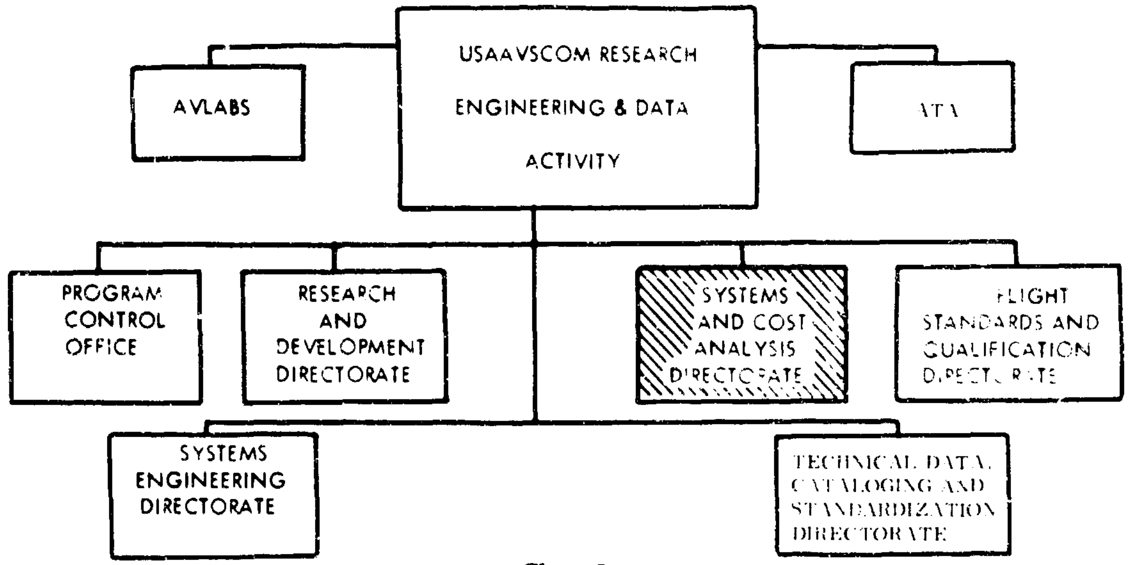

Chart 2

The following outline depicts the mission of the Directorate of Systems and Cost Analysis and the functions of the Systems Analysis Division.

SYSTEMS AND COST ANALYSIS DIRECTORATE

MISSION

Conduct systems analysis/cost-effectiveness studies, cost analysis, and cost and economic information system analysis; provide the command focal point for short and long-range hardware studies, both contractual and inhouse, under AR 1-110 and AMCR 700-10; and technical and economic evaluation and solution of materiel oriented problems throughout the materiel life cycle.

SYSTEMS ANALYSIS DIVISION

FUNCTIONS

a. Perform systems analysis studies and investigations for the command or Headquarters, AMC.

b. Establish the requirement for data banks on subjects which are basic to the command systems analysis activity and provide for and require the identification, collection, and maintenance of such data; develop and maintain data banks on subjects related to systems analysis operations.

c. Provide systems analysis type inputs on data which may be required for larger systems analysis studies performed by the Army Materiel Systems Analysis Center or by other agencies outside of AMC.

d. Initiate systems analysis/cost-effectiveness studies and evaluations of command programs and materiel items, systems or concepts, as may be determined necessary.

e. Review and validate systems analysis type investigations, studies, evaluations, and reports prepared by the command's subordinate activities prior to their submission to higher headquarters, other elements of AMC, or other agencies as inputs.

f. Provide systems analysis assistance and advise in the performance of the total systems analysis effort within the commodity command.

g. Maintain cognizance of all systems analysis type studies and investigations which have been submitted by the command to higher authority.

h. Resolve problems arising in the systems analysis activity within the command as a result of functional interfaces.

i. Develop and establish methodologies and techniques for command use and application on commodity oriented systems analysis studies and activities.

j. Establish an integrated, commodity oriented systems analysis study program and effort (for both short- and long-term objectives) within the commodity command to include those phases which cover the full range in the life cycle of materiel.

k. Maintain liaison and coordinate with the Army Materiel Systems Analysis Center.

l. Perform or provide for training needs in operations research/systems analysis type techniques and methods within the commodity command.

m. Represent the command at various professional meetings and seminars and serves as the command point of contact on matters dealing with Systems Analysis, cost effectiveness, operations research, scientific analysis, logistics research, applied mathematics and mathematical statistics.

n. Develop requests for and monitor and review progress of contract studies.

Chart 3 depicts the Systems and Cost Analysis Directorate organization and structure along with the required and authorized spaces for the Headquarters, the Systems Analysis, the Cost Analysis and the CEIS Divisions. As a matter of interest, the Cost Analysis Division is the only one having Branches within it. The Headquarters is staffed with five personnel–the Director, Deputy Director, Secretary, Clerk Steno and a Management Services Assistant. Of primary concern of course, is the Systems Analysis Division. It is authorized eight civilian personnel and three military. Of these eight civilians, two are Clerical and one is the Chief of the Division. The remaining five civilian spaces are, in essence, the working force of the Systems Analysis Group. Although there are three military spaces associated with this Division, it is very rare that these spaces are ever staffed. Our experience has been one military in the Division for a period of 96 days in the past year. Presently we have no military in this Division. As can be seen, the nucleus of Systems Analysis at the Headquarters is a very small organization limited in resources. Those of you associated with the SAGs throughout the Commodity Commands are in a similar position as we at AVSCOM, in that the workload far overshadows the resources available to meet the demands placed on us.

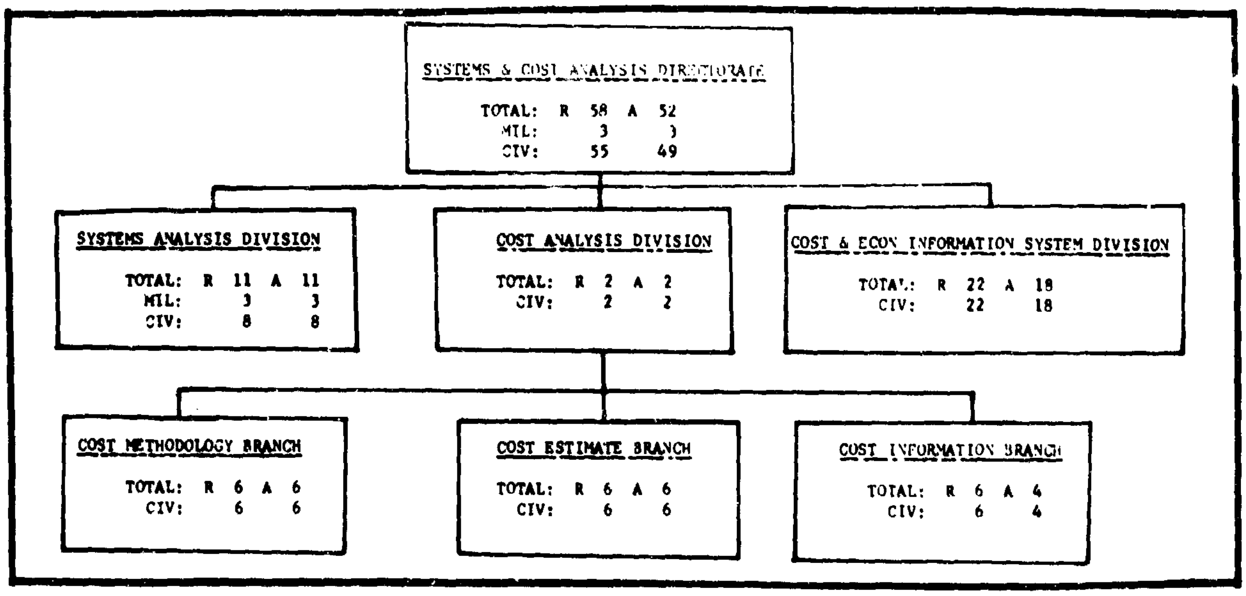

Chart 3

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